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(12) **United States Patent**
**Dar et al.**

(10) **Patent No.: US 9,072,896 B2**
(45) **Date of Patent: Jul. 7, 2015**

(54) **SYSTEM FOR TRANSMITTING ELECTRICAL CURRENT TO A BODILY TISSUE**

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(73) Assignee: **Bioness Inc.**, Valencia, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 262 days.

(21) Appl. No.: **13/513,318**

(22) PCT Filed: **Dec. 1, 2010**

(86) PCT No.: **PCT/US2010/058525**
§ 371 (c)(1),
(2), (4) Date: **Aug. 8, 2012**

(87) PCT Pub. No.: **WO2011/068849**
PCT Pub. Date: **Jun. 9, 2011**

(65) **Prior Publication Data**

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**Related U.S. Application Data**

(63) Continuation-in-part of application No. 12/628,273, filed on Dec. 1, 2009, now Pat. No. 8,738,137, which is a continuation-in-part of application No. 12/197,849, filed on Aug. 25, 2008, now Pat. No. 8,467,880.

(60) Provisional application No. 60/957,592, filed on Aug. 23, 2007.

(51) **Int. Cl.**
***A61N 1/00*** (2006.01)
***A61N 1/36*** (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC ................ ***A61N 1/36*** (2013.01); ***A61N 1/0456*** (2013.01); ***A61N 1/048*** (2013.01); ***A61N 1/0492*** (2013.01);

(Continued)

(58) **Field of Classification Search**
USPC ................................................ 607/2, 46, 152
See application file for complete search history.

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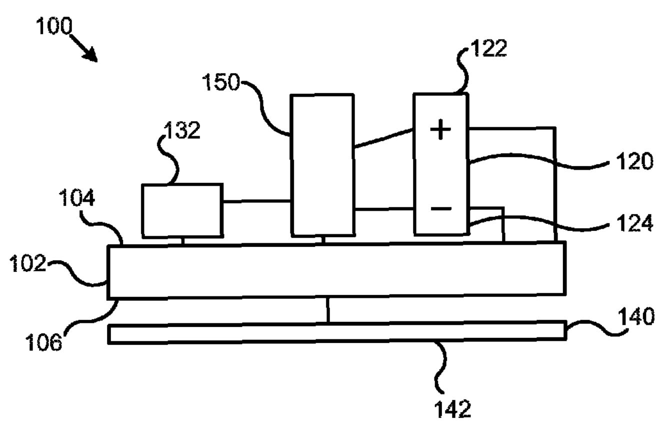
*Primary Examiner* — Christopher D Koharski
*Assistant Examiner* — Nadia A Mahmood
(74) *Attorney, Agent, or Firm* — Cooley LLP

(57) **ABSTRACT**

In some embodiments, an apparatus includes a substantially rigid base and a flexible substrate. The substantially rigid base has a first protrusion and a second protrusion, and is configured to be coupled to an electronic device. The flexible substrate has a first surface and a second surface, and includes an electrical circuit configured to electronically couple the electronic device to at least one of an electrode a battery, or an antenna. The flexible substrate is coupled to the base such that a first portion of the second surface is in contact with the first protrusion. A second portion of the second surface is non-parallel to the first portion.

**20 Claims, 25 Drawing Sheets**



(51) **Int. Cl.**
***A61N 1/04*** (2006.01)
***A61N 1/375*** (2006.01)
*A61N 1/362* (2006.01)

(52) **U.S. Cl.**
CPC ............ ***A61N 1/36021*** (2013.01); ***A61N 1/375*** (2013.01); ***A61N 1/04*** (2013.01); *A61N 1/0472* (2013.01); *A61N 1/36017* (2013.01); *A61N 1/3625* (2013.01); *A61N 1/3756* (2013.01); *A61N 1/3758* (2013.01)

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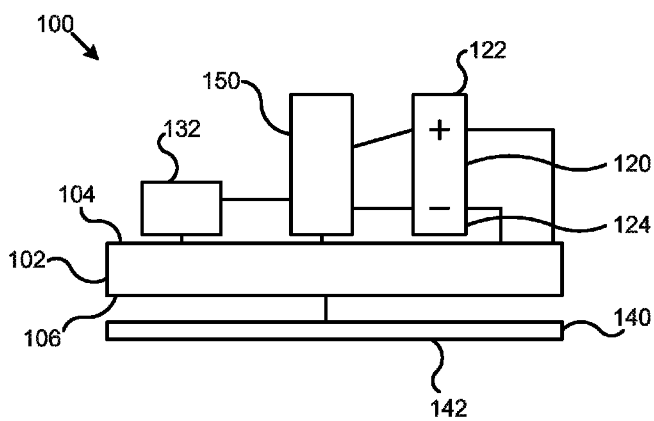



FIG. 1

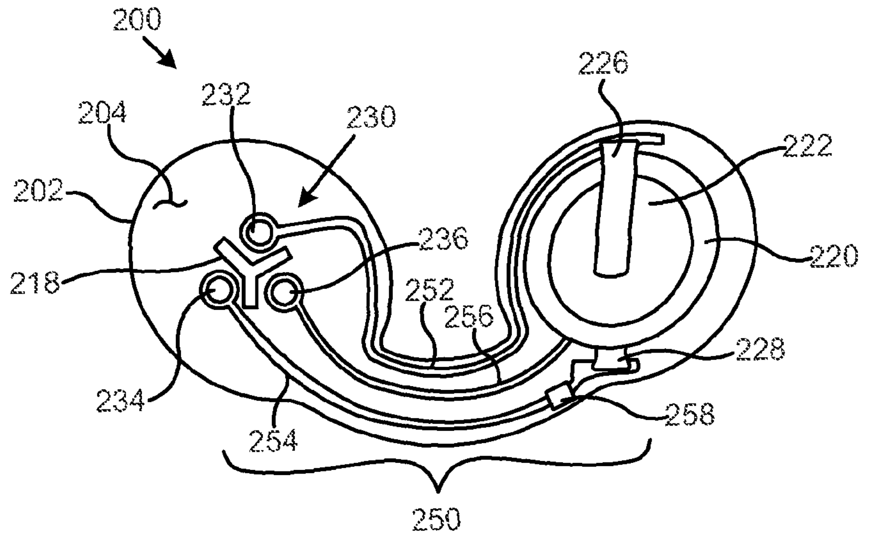



FIG. 2

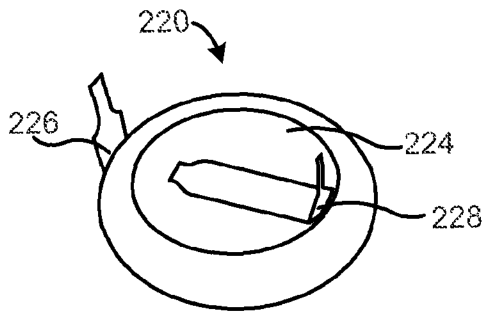



FIG. 3A

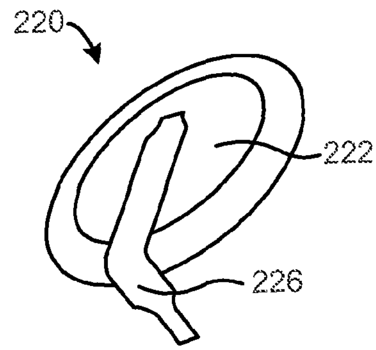



FIG. 3B

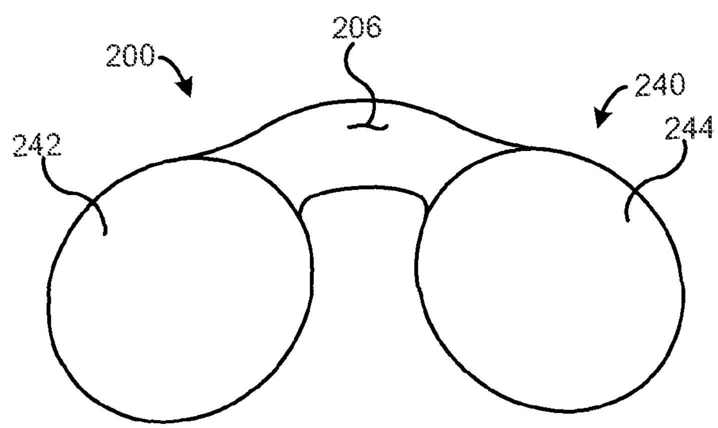



FIG. 4

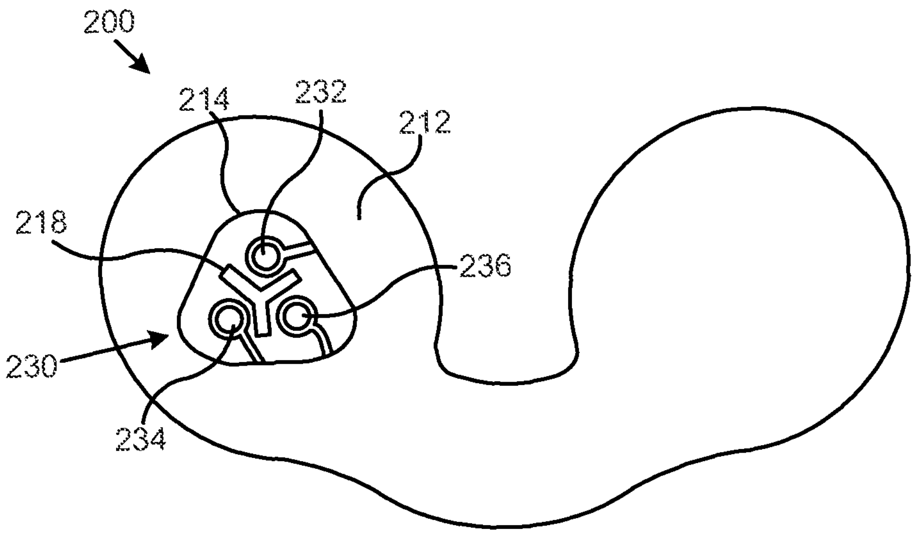
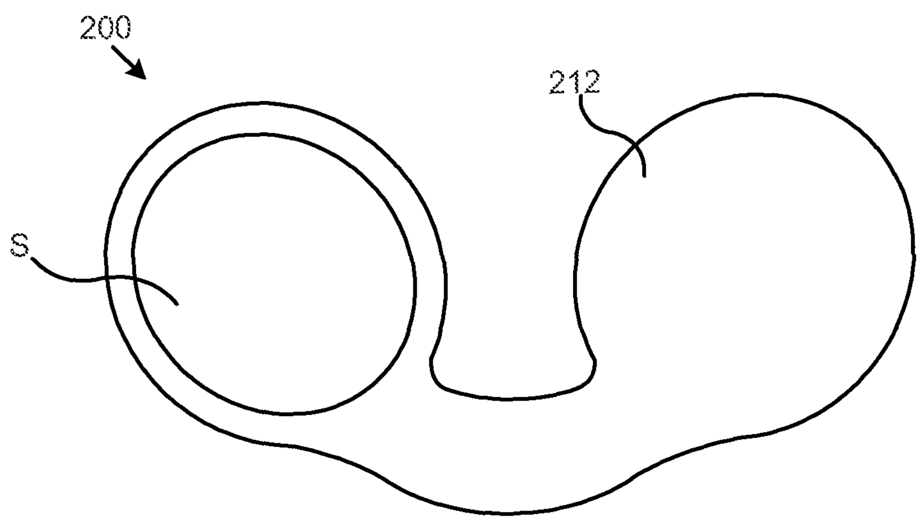



FIG. 5

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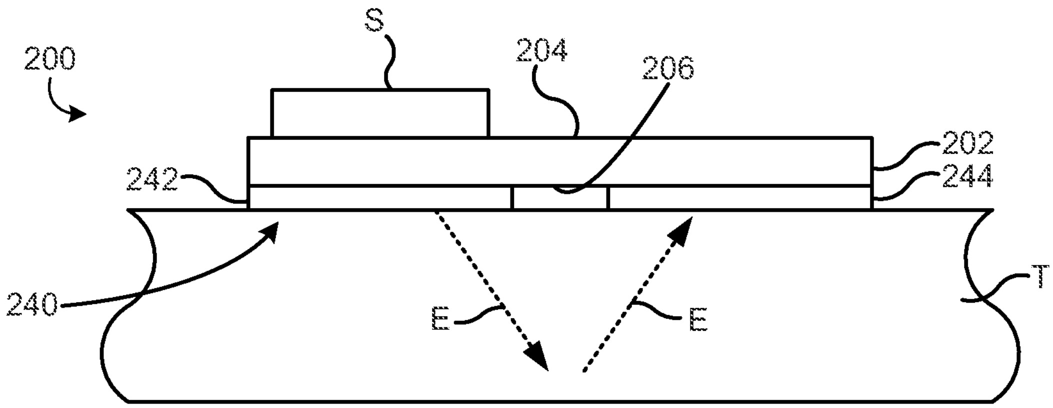
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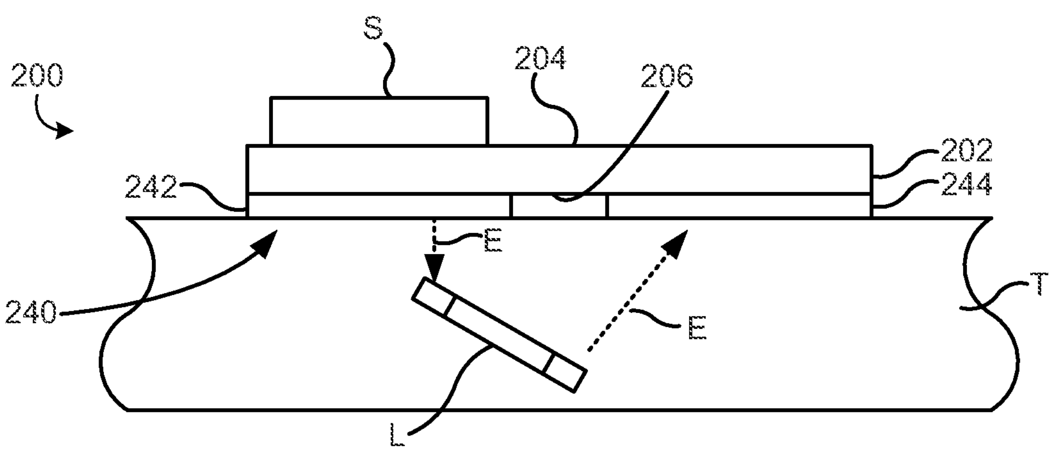
FIG. 7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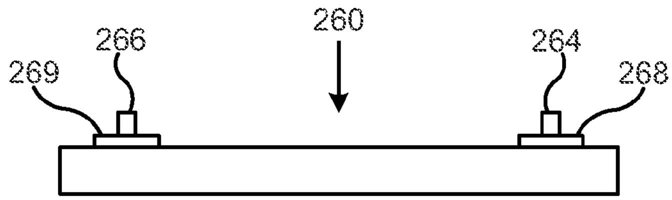
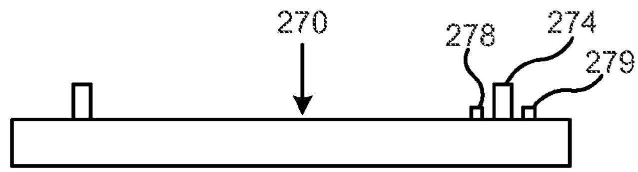



FIG. 9A

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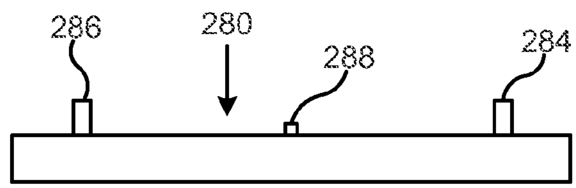
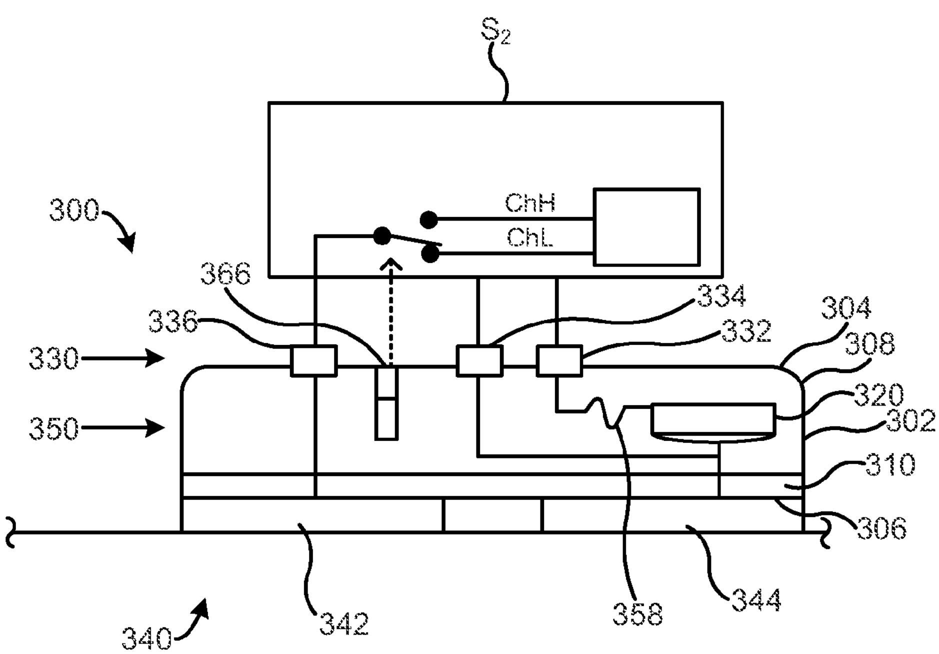



FIG. 9C

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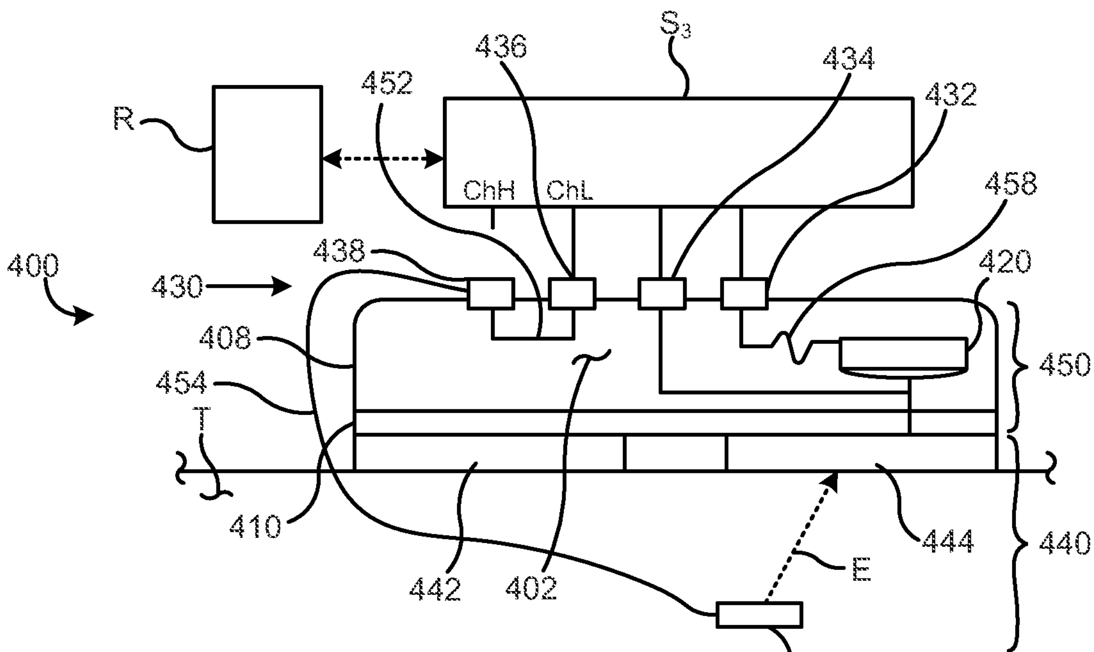

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FIG. 11

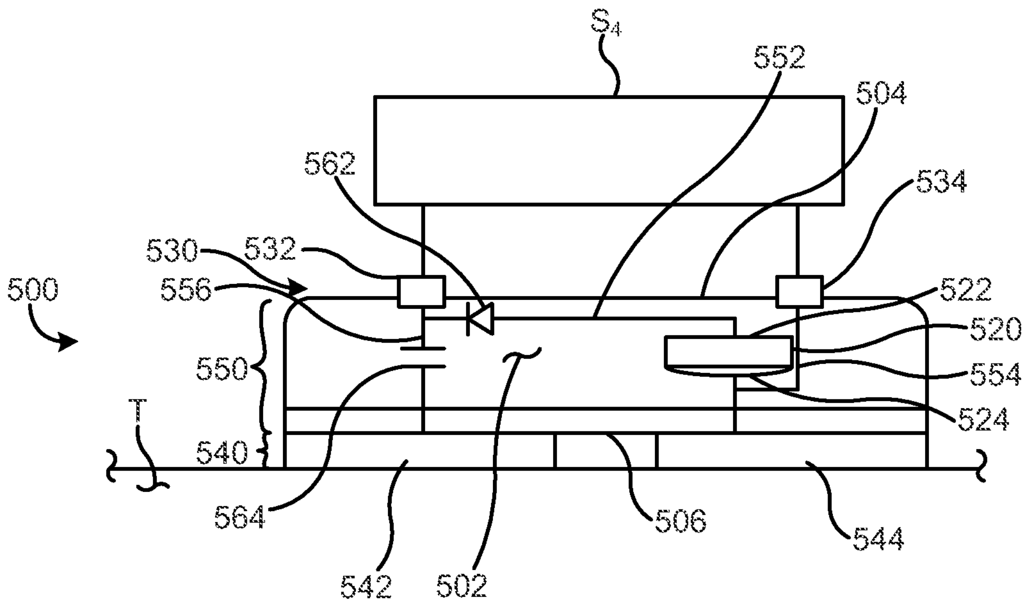

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FIG. 12

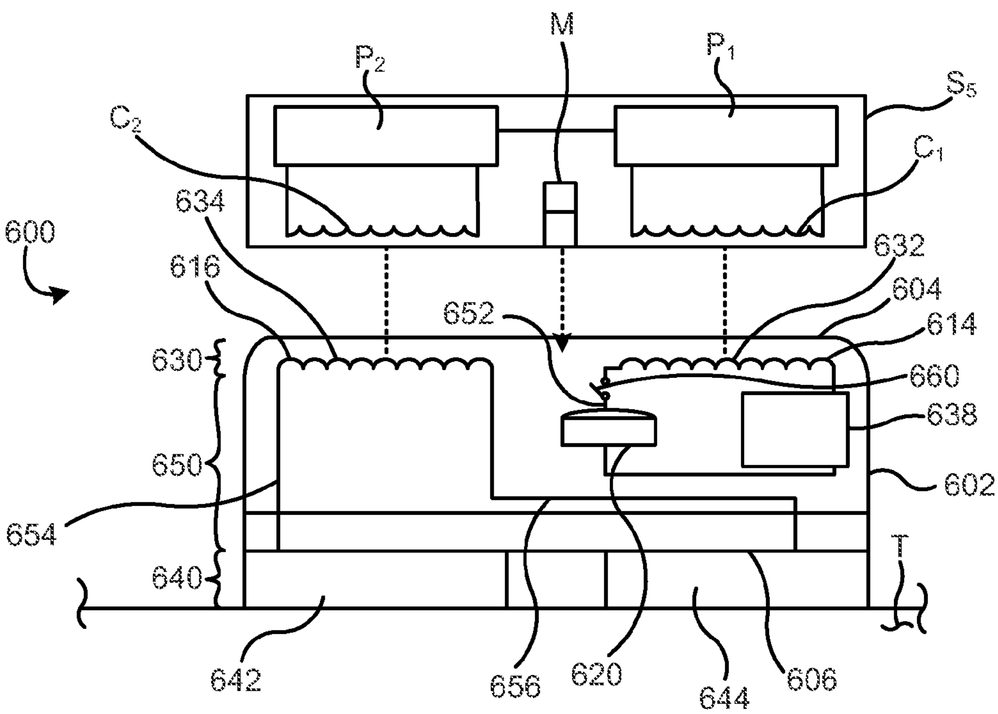
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FIG. 13

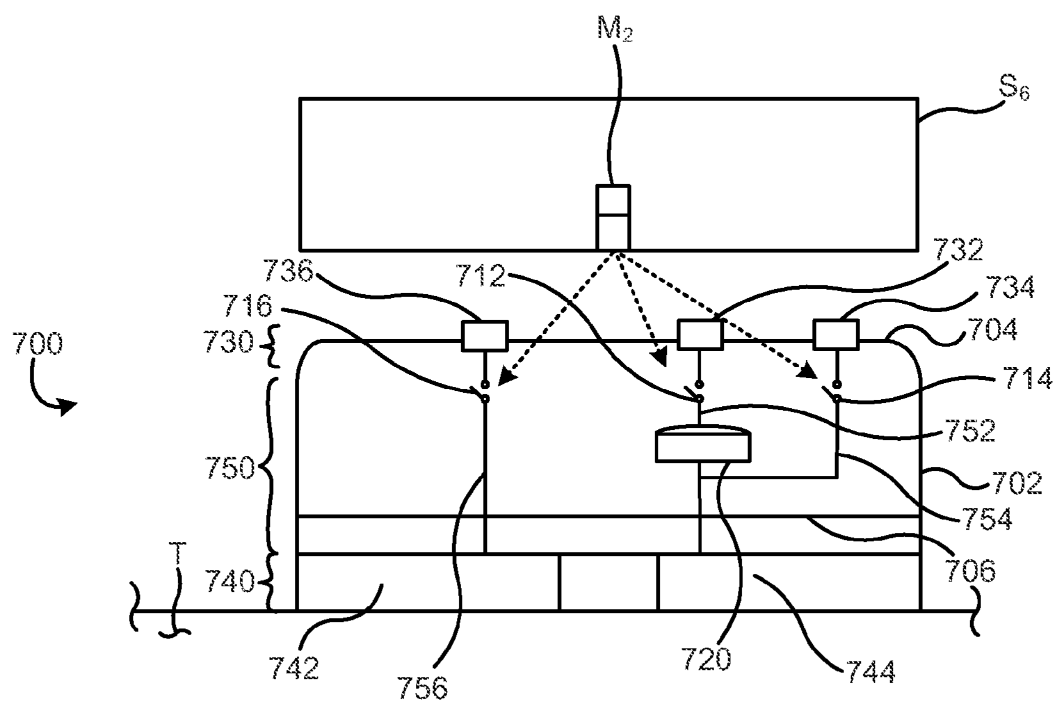
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FIG. 14

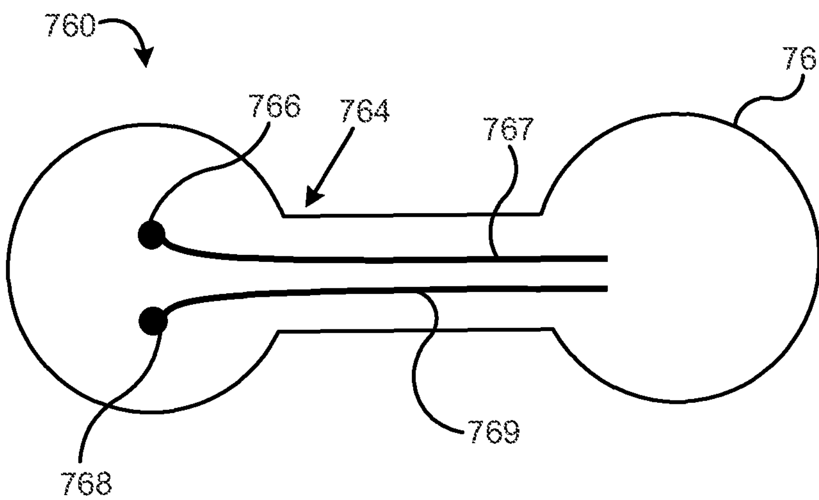
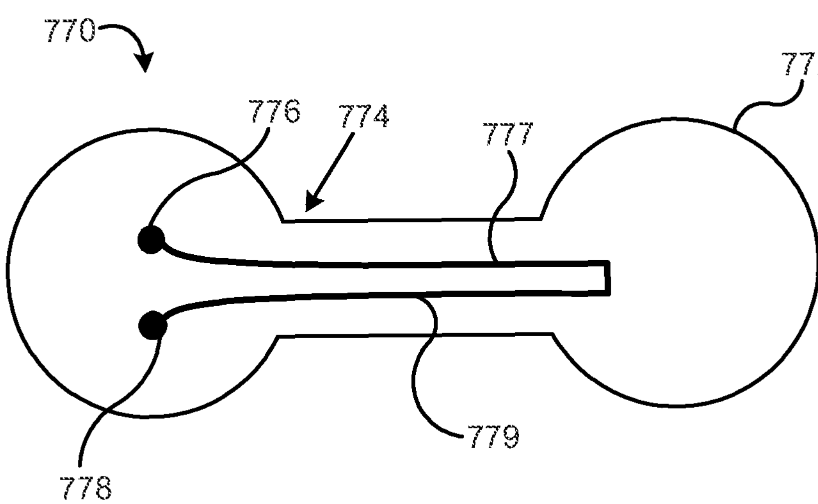



FIG. 15

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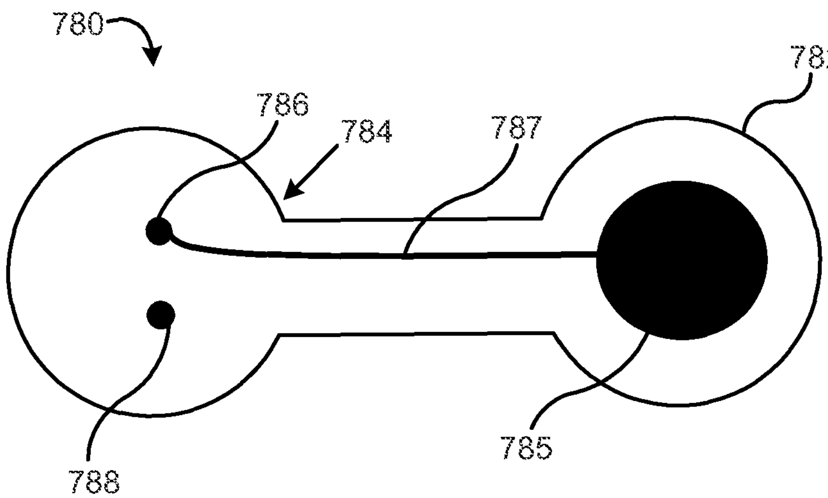


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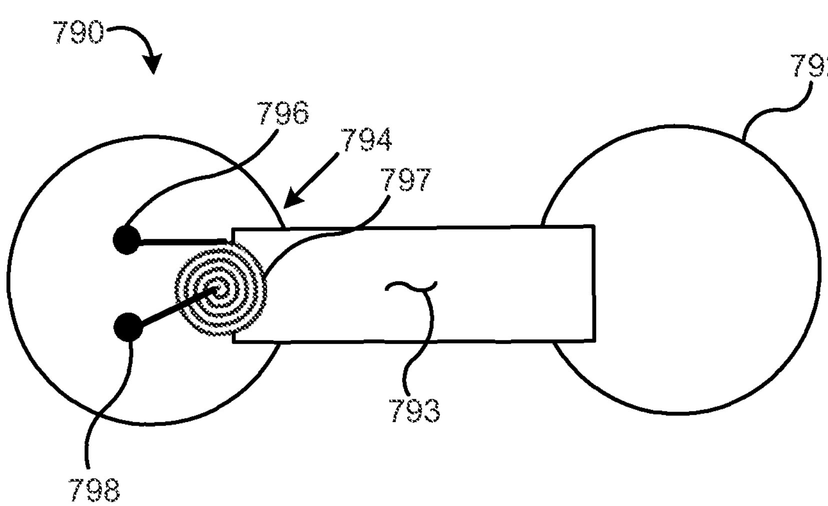


FIG. 18

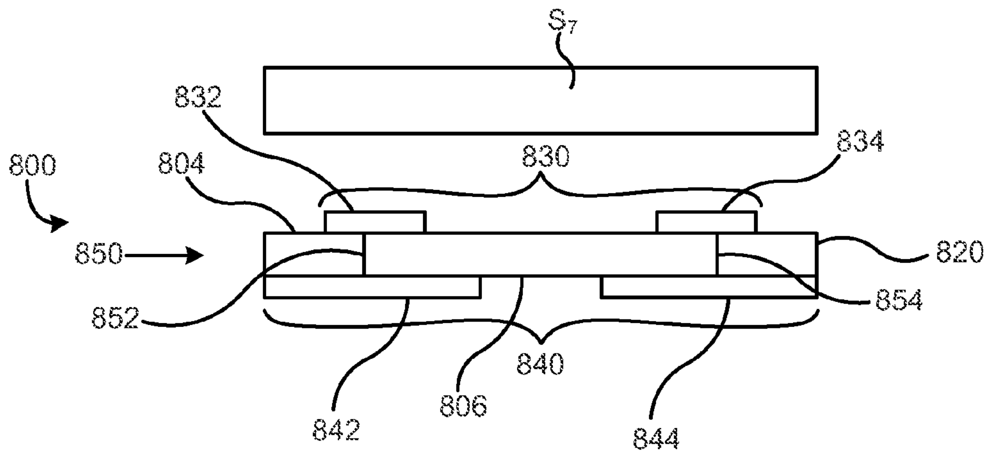

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FIG. 19

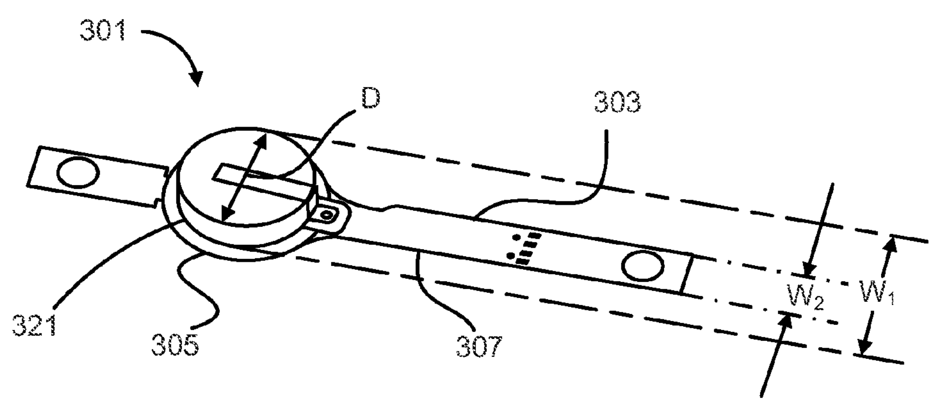

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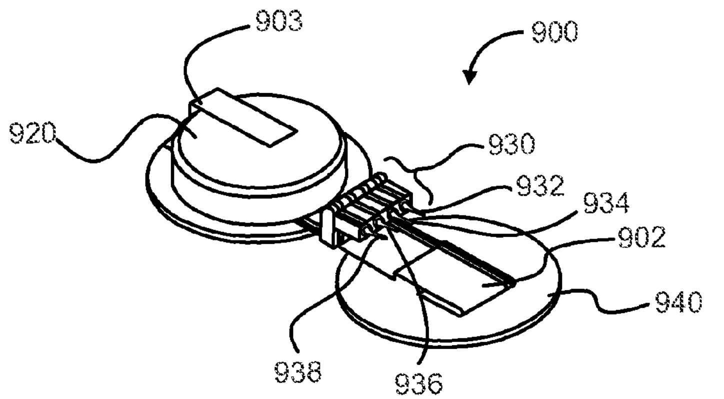
FIG. 20

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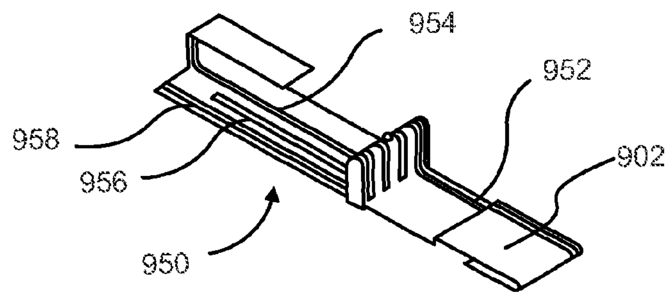



FIG. 22

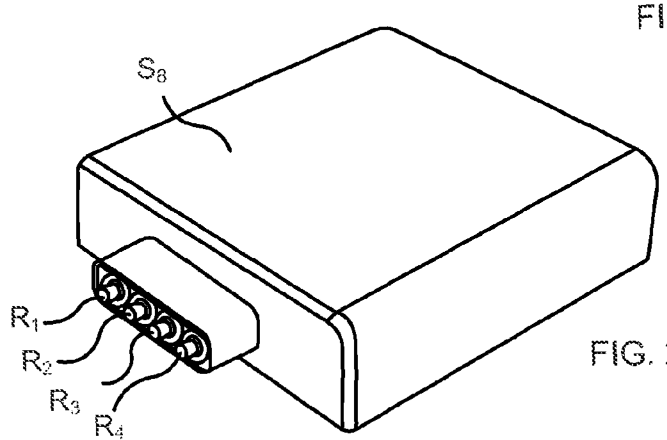



FIG. 23

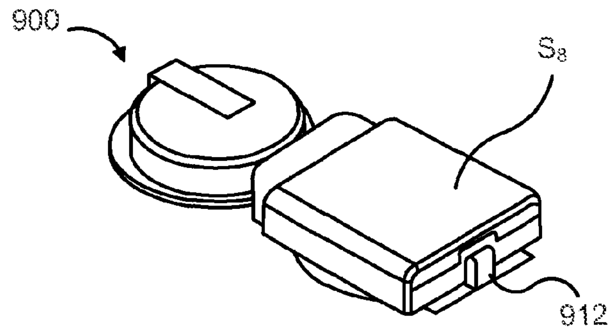



FIG. 24

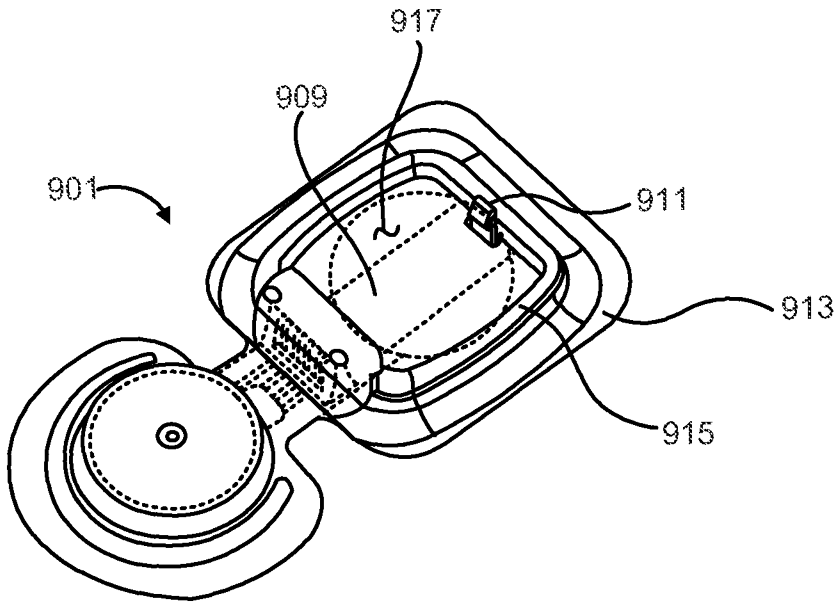



FIG. 25

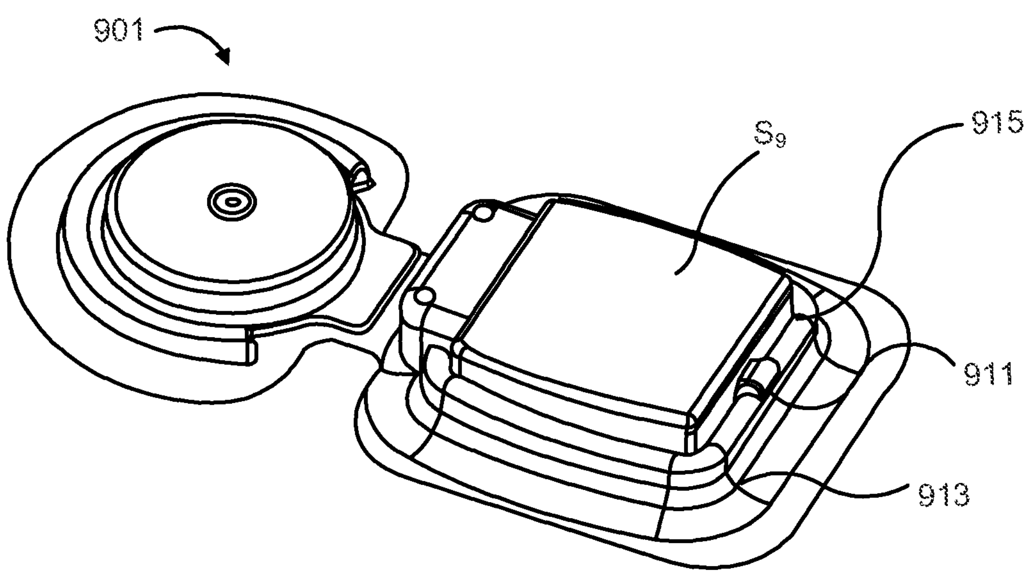



FIG. 26

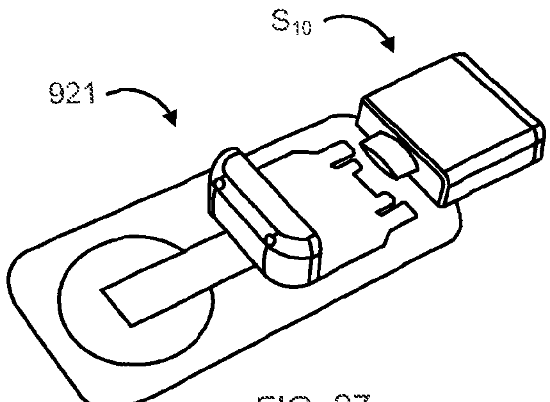



FIG. 27

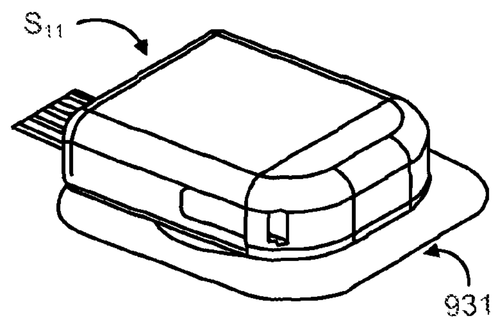



FIG. 28

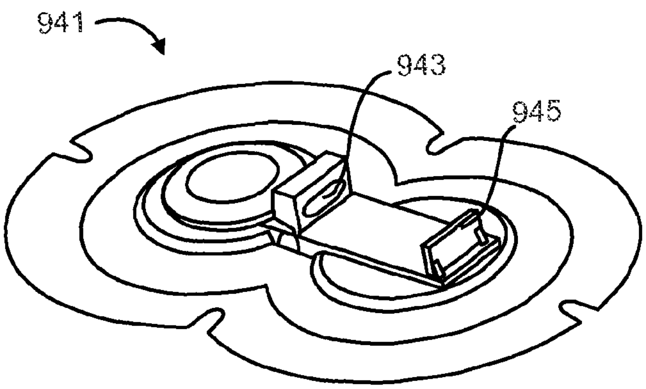



FIG. 29

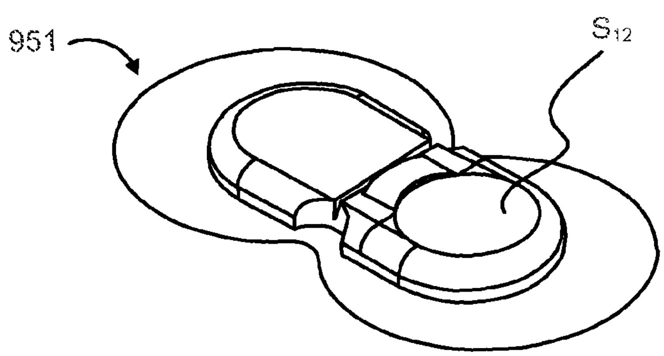



FIG. 30

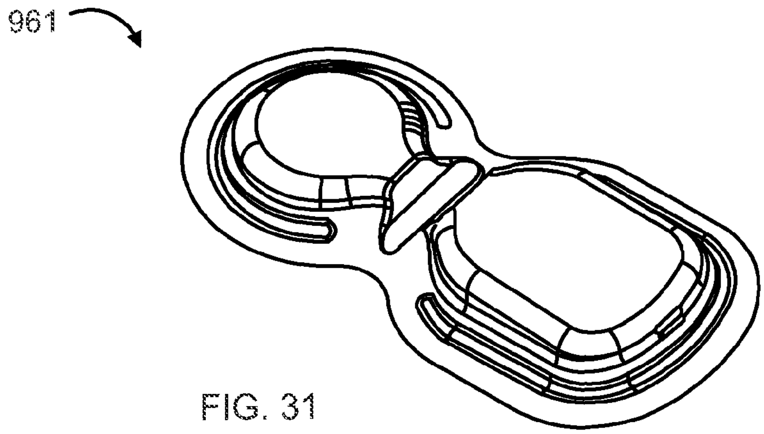



FIG. 31

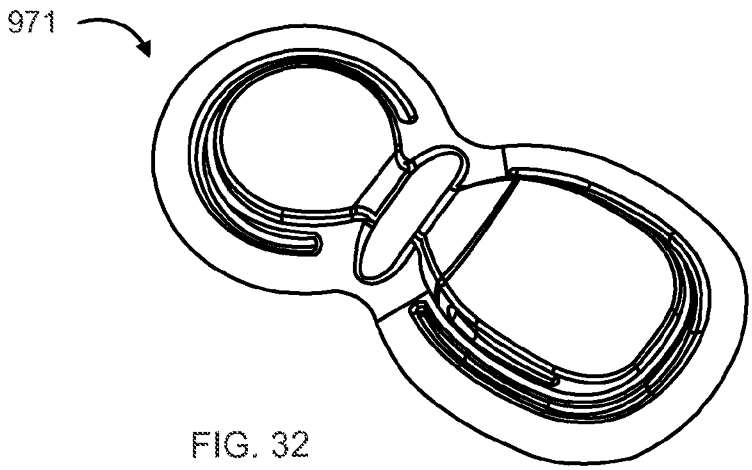



FIG. 32

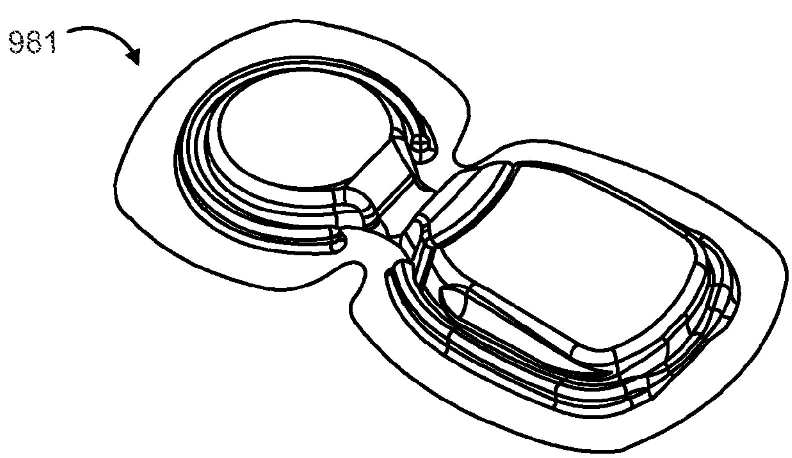



FIG. 33

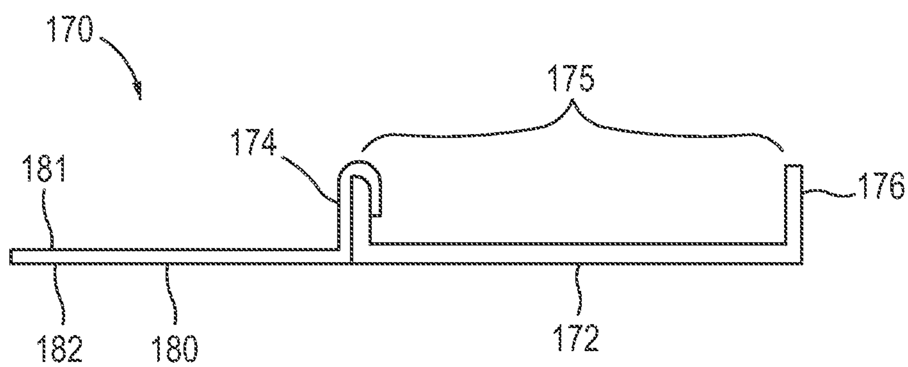



FIG. 34

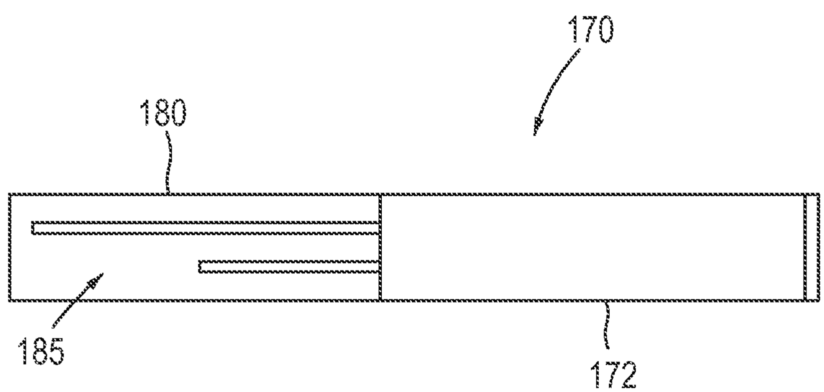



FIG. 35

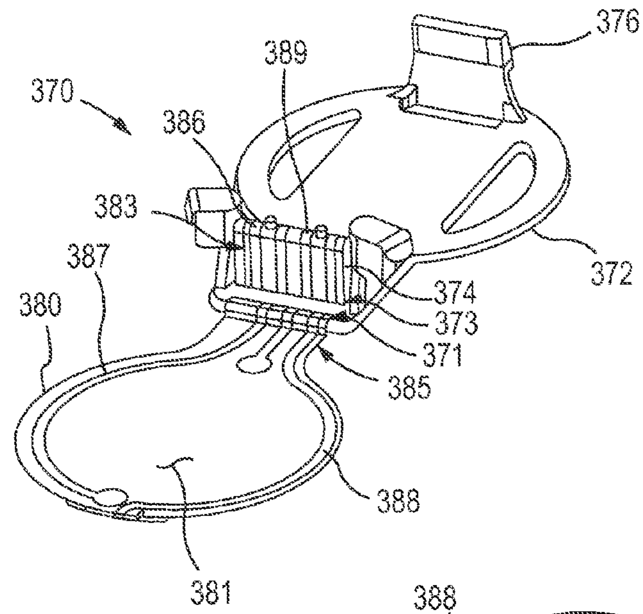



FIG. 36

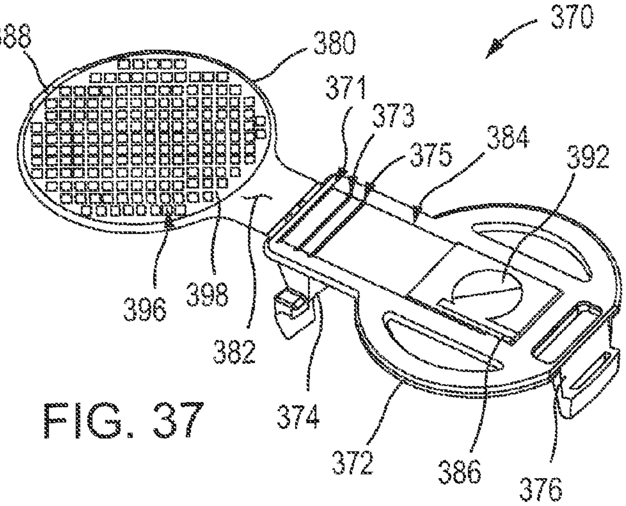



FIG. 37

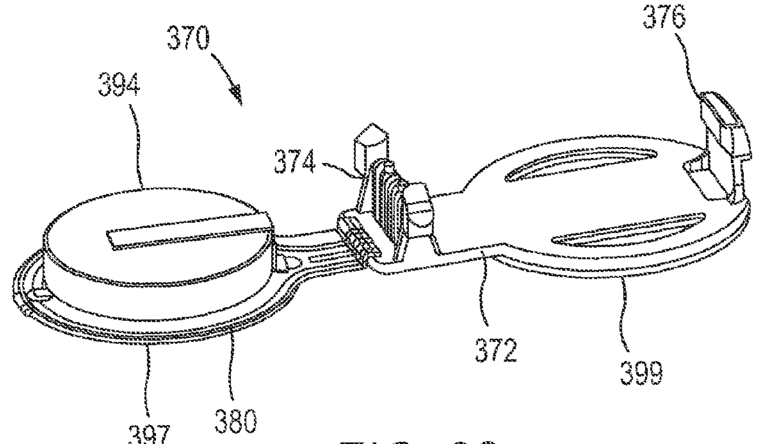
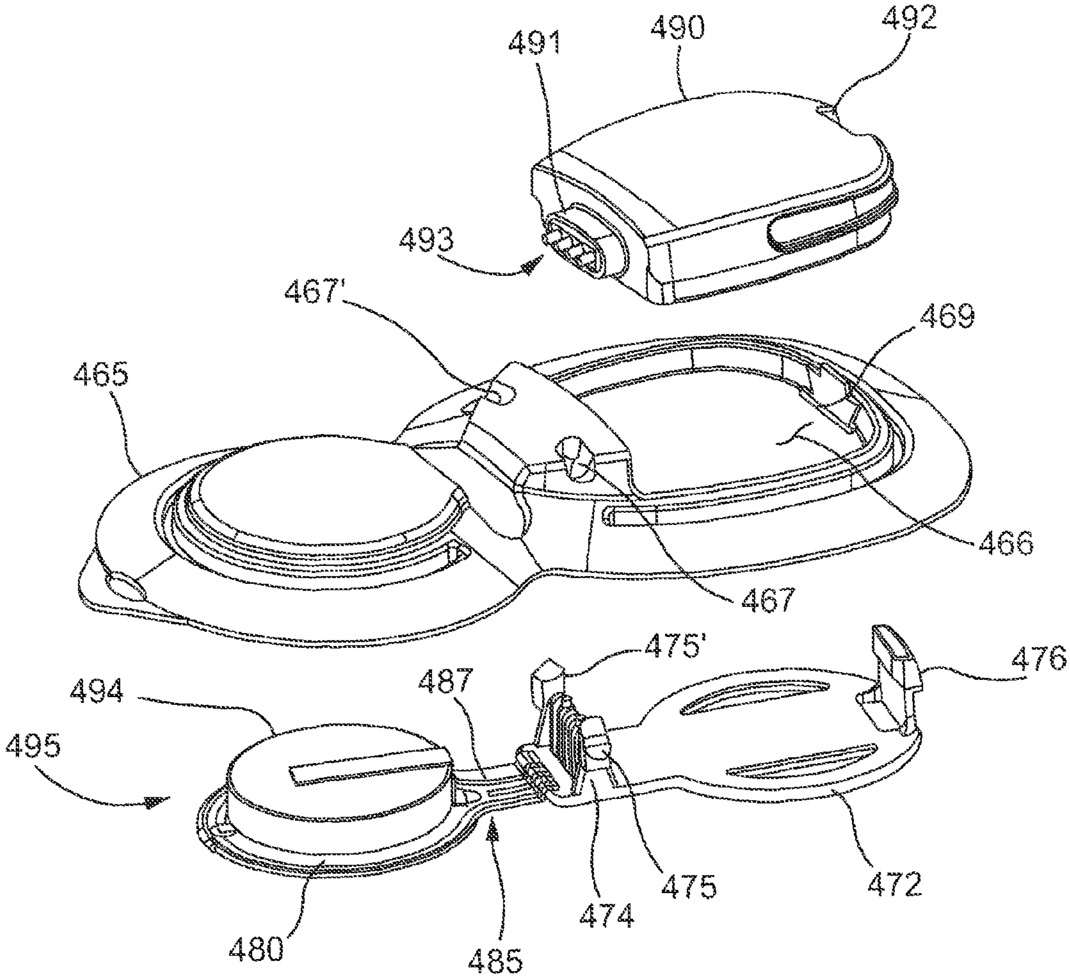



FIG. 38



490
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475'
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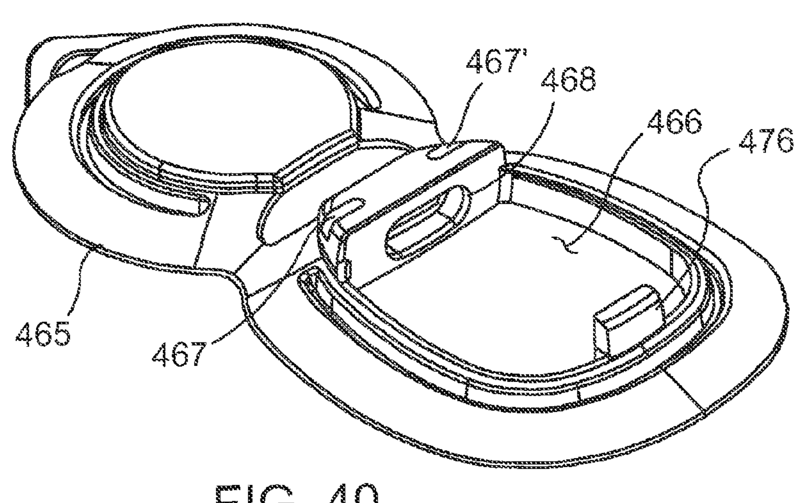
485


FIG. 39



467'
468
466
476
465
467


FIG. 40

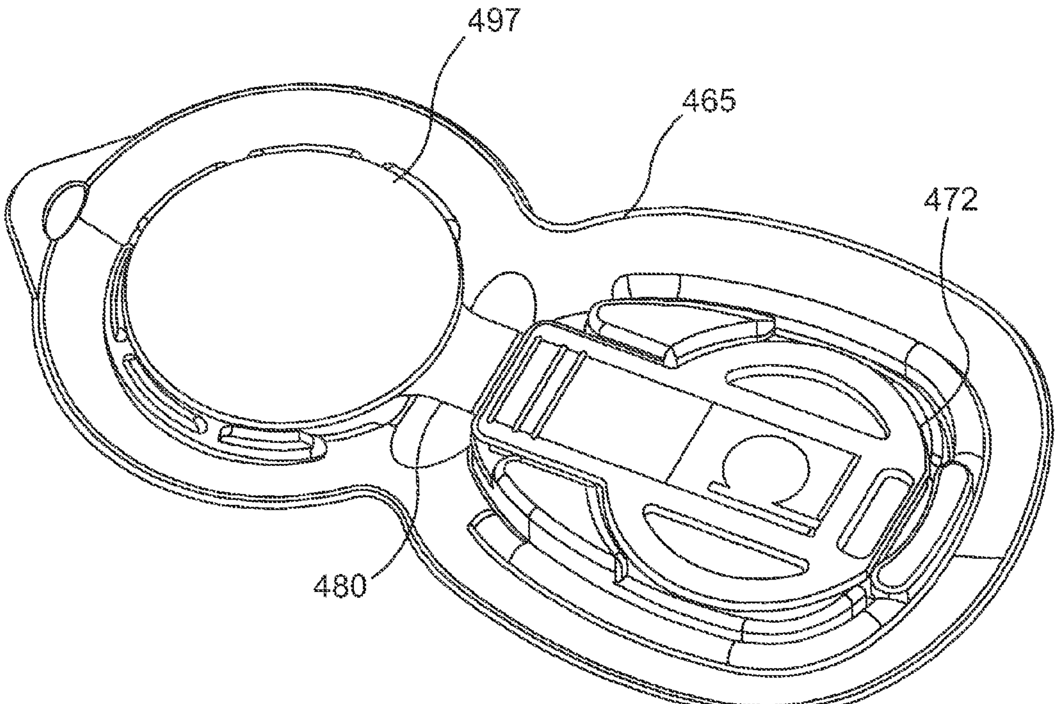



FIG. 41

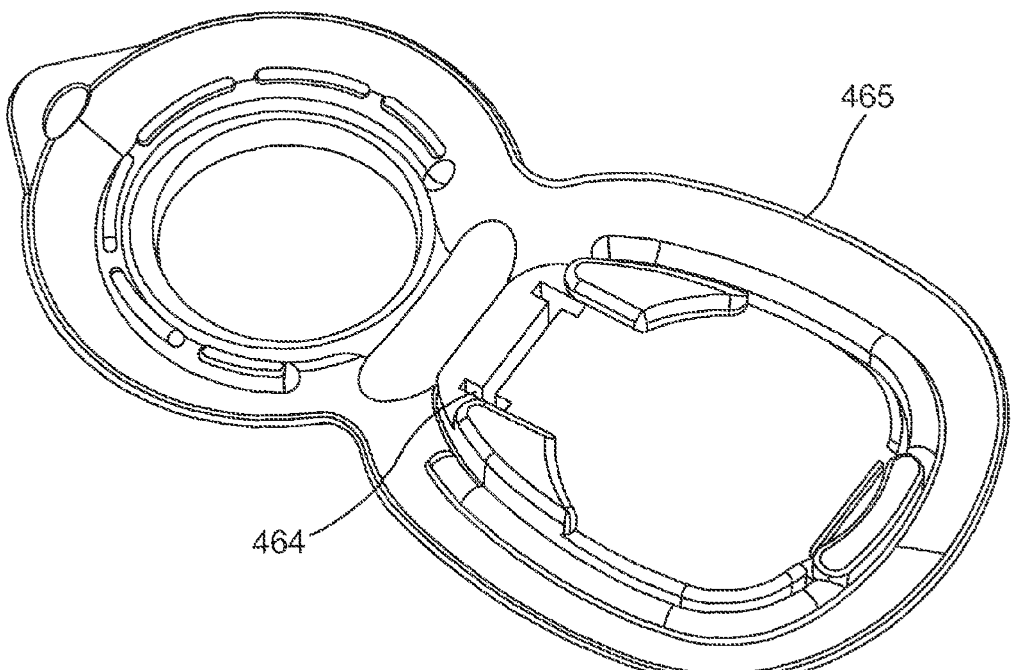
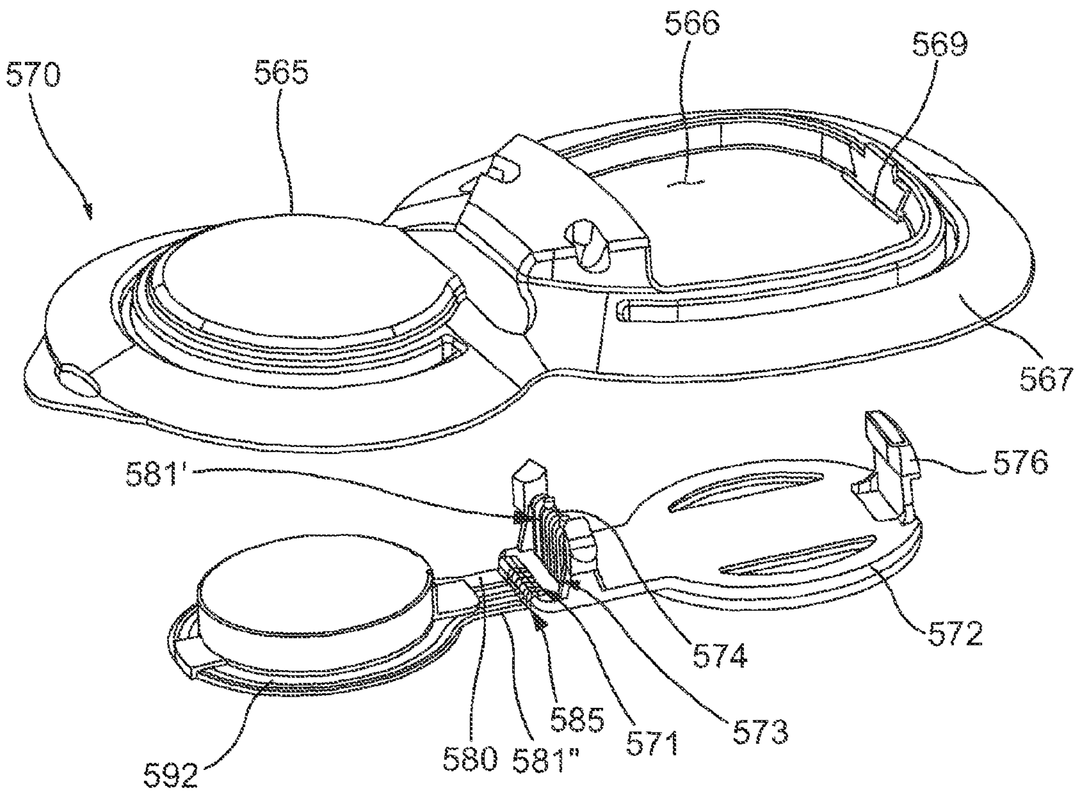



FIG. 42



570
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566
569
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581'
576
572
574
573
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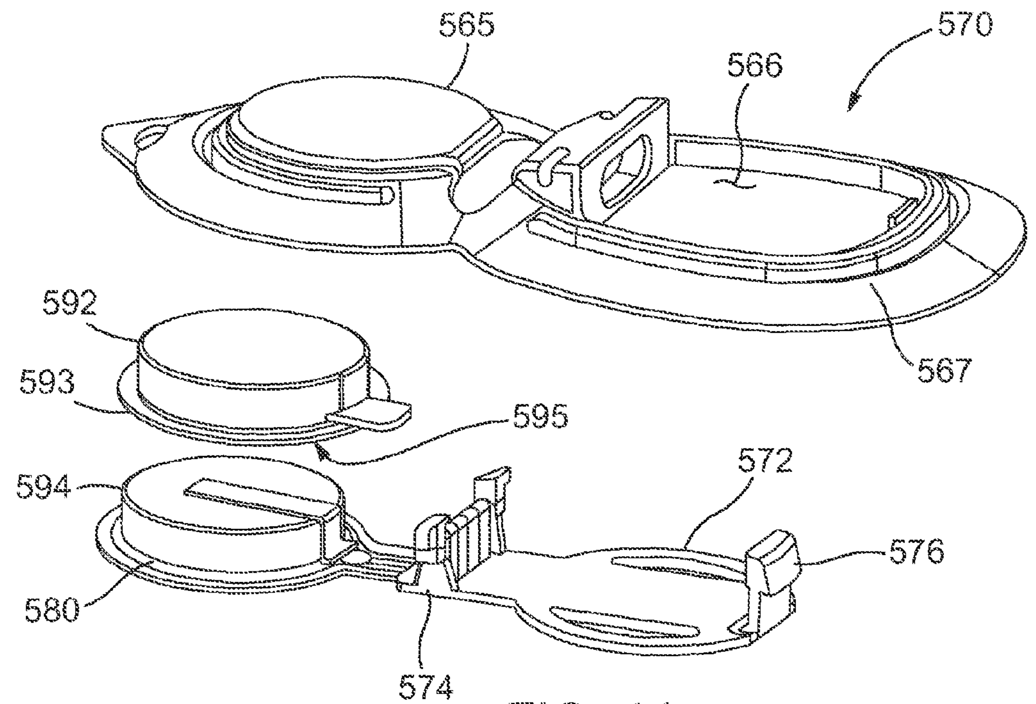
571
592
580
581"


FIG. 43



565
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574


FIG. 44

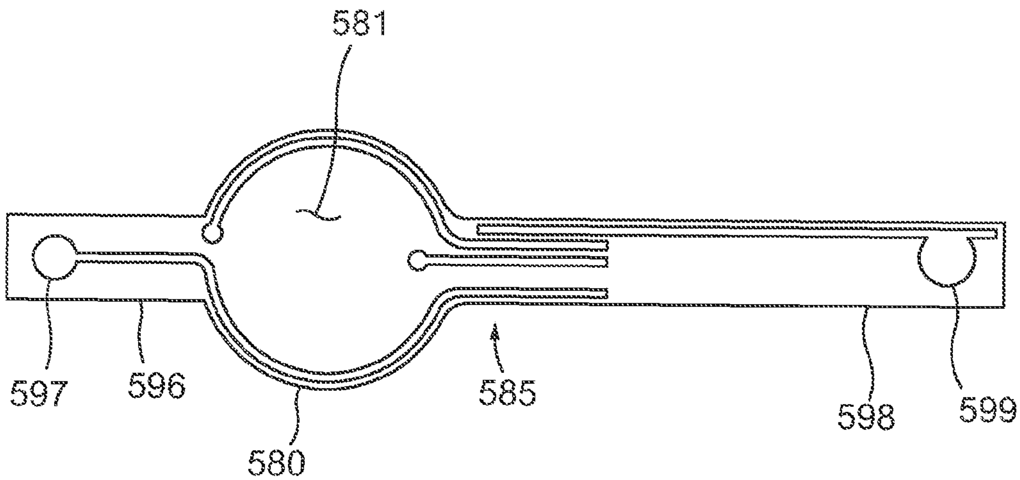


FIG. 45

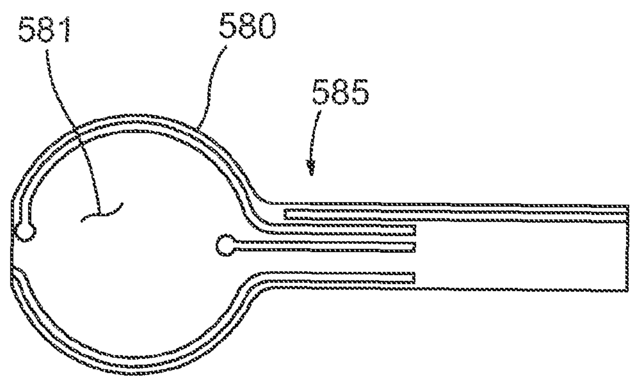


FIG. 46

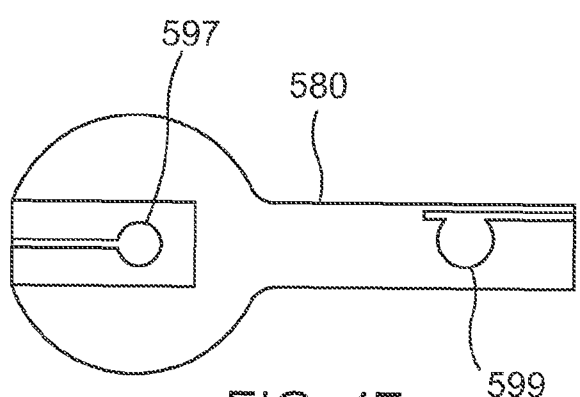


FIG. 47

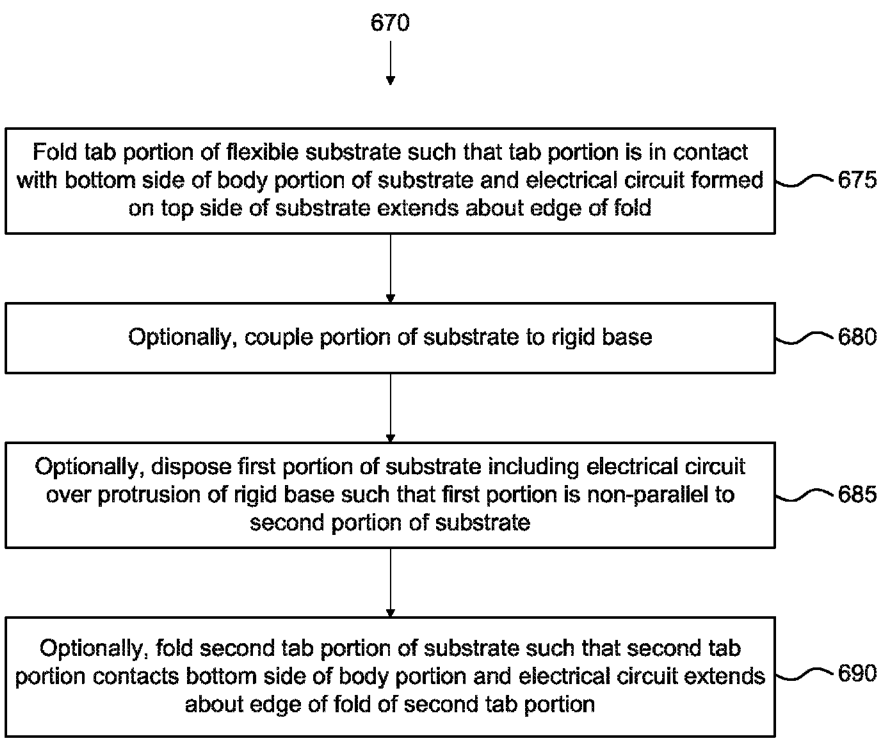
670
Fold tab portion of flexible substrate such that tab portion is in contact with bottom side of body portion of substrate and electrical circuit formed on top side of substrate extends about edge of fold
675
Optionally, couple portion of substrate to rigid base
680
Optionally, dispose first portion of substrate including electrical circuit over protrusion of rigid base such that first portion is non-parallel to second portion of substrate
685
Optionally, fold second tab portion of substrate such that second tab portion contacts bottom side of body portion and electrical circuit extends about edge of fold of second tab portion
690

FIG. 48

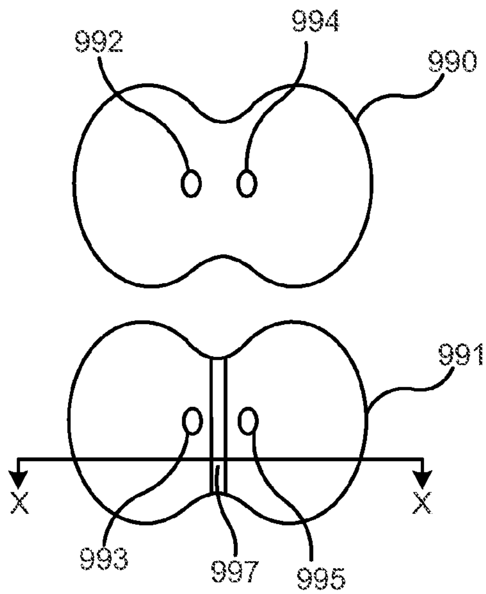


FIG. 49

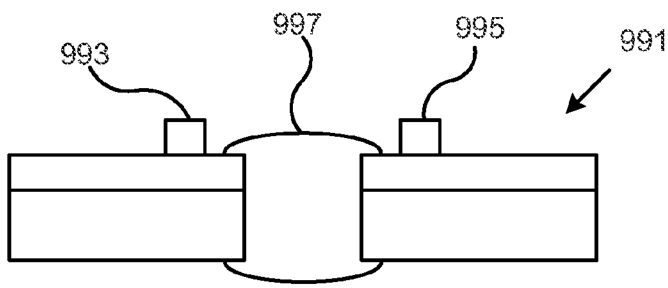


FIG. 50

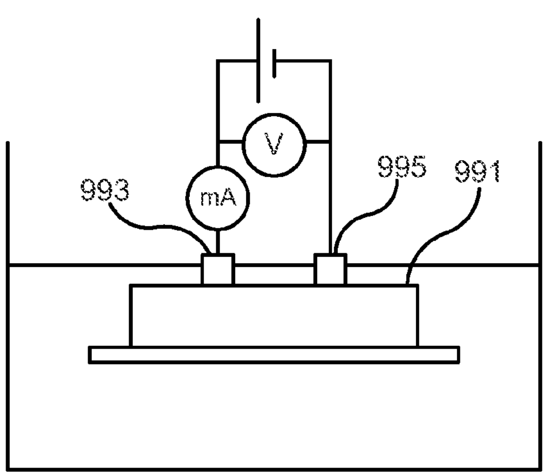


FIG. 51

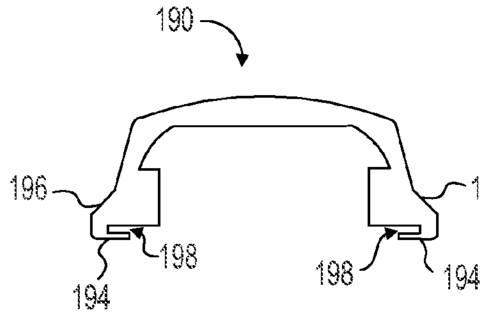


FIG. 52

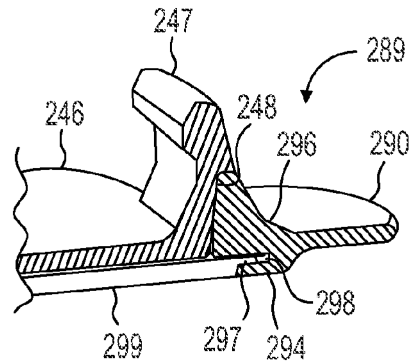


FIG. 53

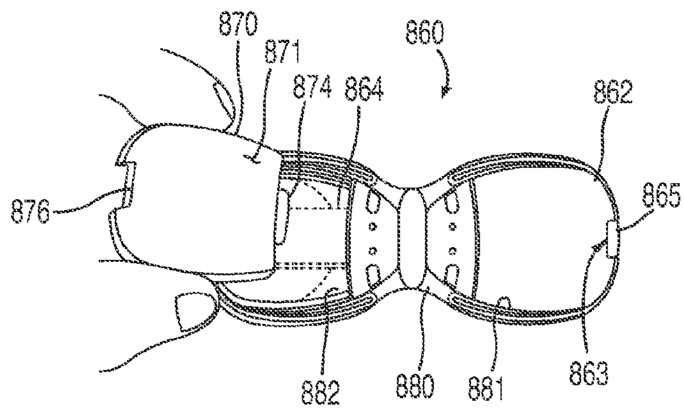


FIG. 54

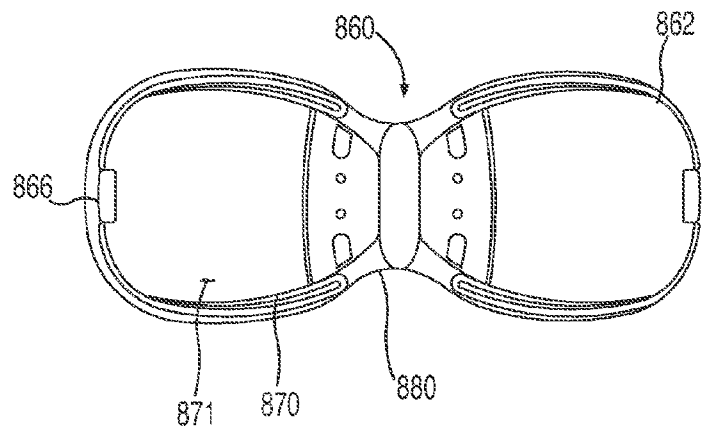


FIG. 55

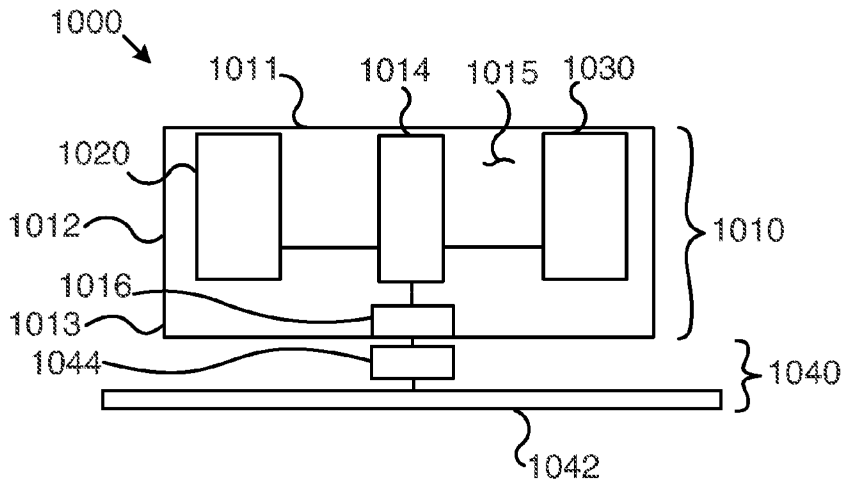


FIG. 56

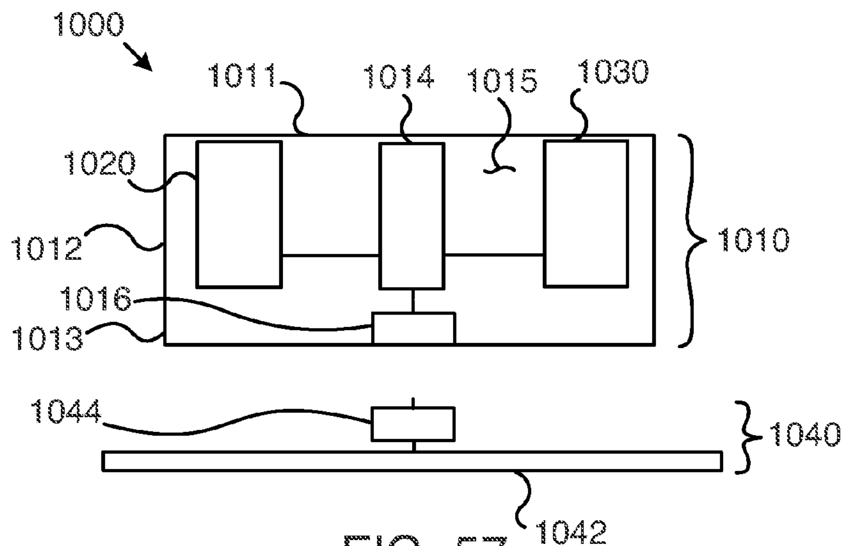


FIG. 57

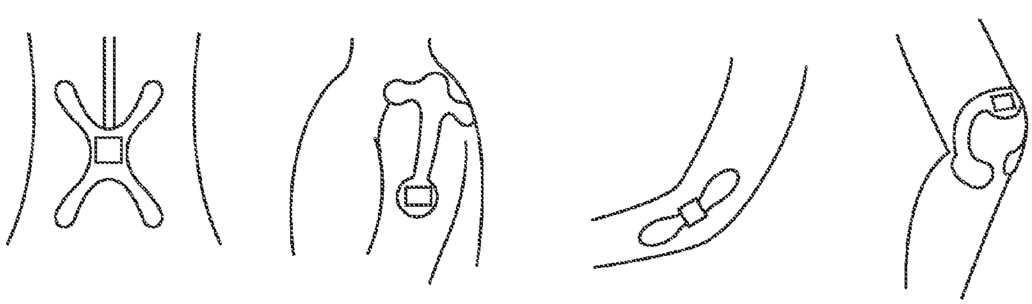

FIG. 58A FIG. 58B FIG. 58C FIG. 58D

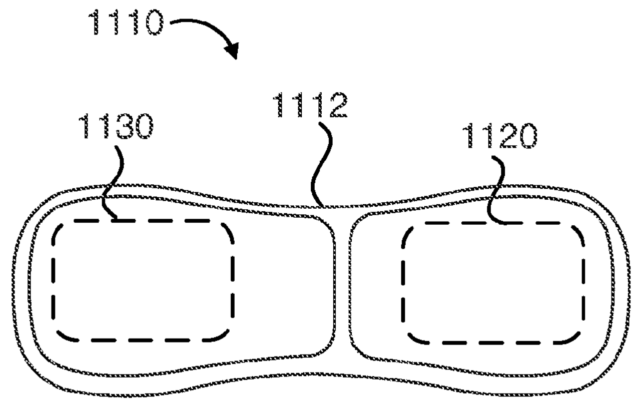


FIG. 59

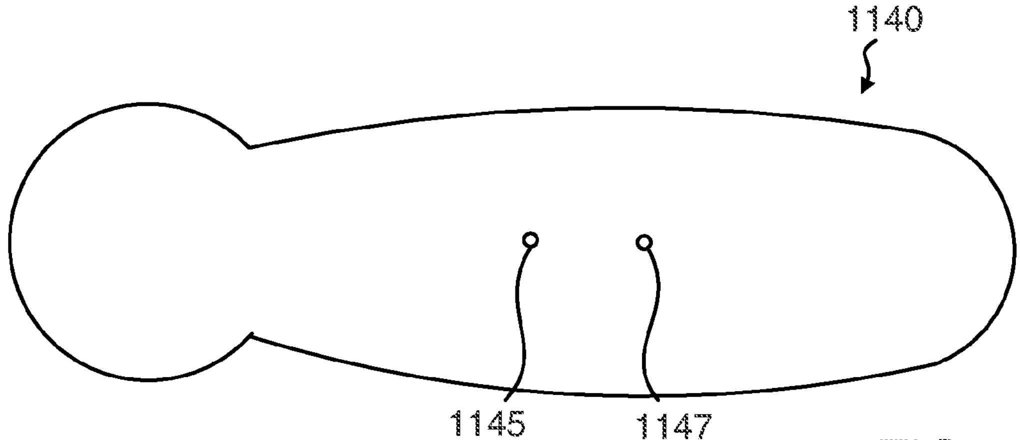


FIG. 60

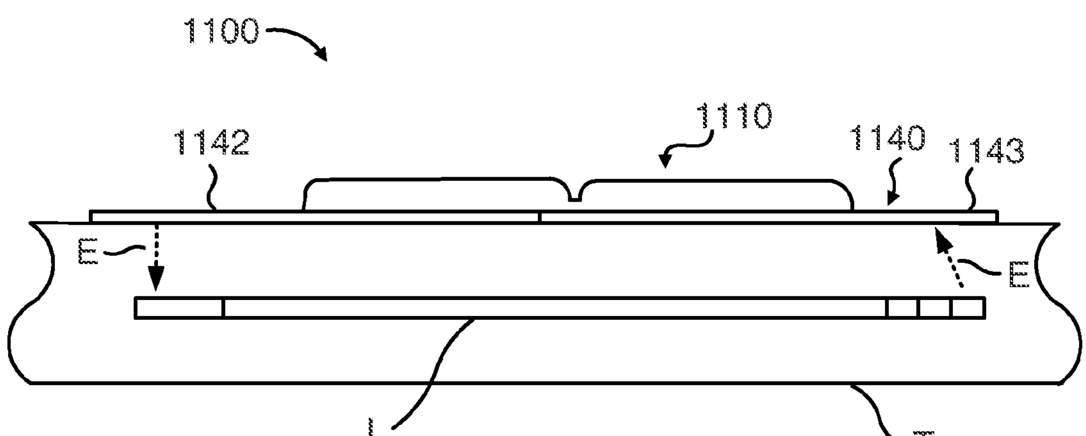


FIG. 61

# SYSTEM FOR TRANSMITTING ELECTRICAL CURRENT TO A BODILY TISSUE

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Stage Entry of and claims priority under 35 U.S.C. §§120 and 371 to International Patent Application No. PCT/US2010/058525 filed Dec. 1, 2010, which is a continuation-in-part of U.S. patent application Ser. No. 12/628,273 filed Dec. 1, 2009, now U.S. Pat. No. 8,738,137, which is a continuation-in-part of U.S. patent application Ser. No. 12/197,849 filed Aug. 25, 2008, now U.S. Pat. No. 8,467,880, which claims priority to U.S. Provisional Application Ser. No. 60/957,592 filed Aug. 23, 2007, each of which is entitled "System for Transmitting Electrical Current to a Bodily Tissue," and each of which is incorporated herein by reference in its entirety.

## BACKGROUND

The invention relates generally to medical devices, and specifically to a device for transmitting an electrical stimulation to a bodily tissue of a patient.

Known electrical stimulation systems are used in various medical procedures. For example, some known electrical stimulation systems are used to stimulate a response from a bodily organ or tissue of a patient, such as, for example, the heart, a muscle group or the like. Some known electrical stimulation systems are used to treat acute and/or chronic pain. One known electrical stimulation system, for example, is a transcutaneous electrical nerve stimulation (TENS) unit that provides an electrical stimulation to an electrode attached to the skin of the patient. The TENS unit includes a battery that must be sufficiently large to provide enough energy for a desired treatment period, often a period of several months, of electrical stimulation before replacement. Such a battery, however, may be obtrusive and/or burdensome for a patient to wear, for example, when the patient is in a long-term treatment program. The TENS unit is connected to the skin electrodes by wires extending from the unit to the electrodes. Exposure of such wires to moisture or fluid, for example as occurs during bathing, swimming, and/or perspiration, may result in unintended current loss or transfer, or shorting of the battery. The presence of such wires can also be cumbersome and/or aesthetically unappealing for the patient. Furthermore, the electrode can lose its electrical and/or mechanical properties within several days, so regular replacement of the electrode is required.

Some known systems are configured for use with a shorter-life battery; however, the system must be designed with a housing that can be opened to remove a used battery and to insert a new battery. Such a design can result in a bulky device that must be worn by the patient.

Some known systems necessitate several connections between an electrode patch and a stimulator. For example, known systems can include three or four connections between the patch and the stimulator. Each additional connection increases the risk that the battery and/or the electrical circuit can be shorted, for example due to the connectors being exposed to moisture, as described above.

What is needed is a compact medical device having a smaller battery configured to provide power for a greater duration or a duration similar to the length of time during which an electrode retains its electrical and/or mechanical properties on a body of a patient. A need also exists for a



compact medical device having a rechargeable battery configured to be rechargeable over a greater period of time and that is removably couplable to a disposable electrode base. A need also exists for a compact medical device that is configured to reduce the risk of a short circuit and/or leakage of an electrical current, such as by having a reduced number of mechanical connections with an external stimulator and/or by having water-resistant components. A need exists for a medical device capable of conforming to the curvature of a bodily tissue and providing structural integrity to support an electronic device. A need also exists for a medical device having a simplified manufacturing and/or assembly process.

## SUMMARY OF THE INVENTION

In some embodiments, an apparatus includes a substantially rigid base and a flexible substrate. The substantially rigid base has a first protrusion and a second protrusion, and is configured to be coupled to an electronic device. The flexible substrate has a first surface and a second surface, and includes an electrical circuit configured to electronically couple the electronic device to at least one of an electrode a battery, or an antenna. The flexible substrate is coupled to the base such that a first portion of the second surface is in contact with the first protrusion. A second portion of the second surface is non-parallel to the first portion.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an apparatus according to an embodiment.

FIG. **2** is a top view of an apparatus according to an embodiment.

FIGS. **3**A-**3**B are perspective views of a negative terminal and a positive terminal, respectively, of a portion of the apparatus of FIG. **2**.

FIG. **4** is a bottom view of the apparatus of FIG. **2**.

FIG. **5** is a top view of the apparatus of FIG. **2** with a portion of the apparatus in a covering.

FIG. **6** is a top view of the apparatus of FIG. **5** coupled to an external stimulator.

FIGS. **7**-**8** are side views of the apparatus of FIG. **2** coupled to an external stimulator and disposed on bodily tissue and delivering an electrical current to the bodily tissue and to an implanted conductive lead, respectively.

FIGS. **9**A-**9**C are side views of portions of apparatus according to embodiments.

FIGS. **10**-**14** are side views of an apparatus according to embodiments and an external stimulator.

FIGS. **15**-**18** are top views of an antenna of an apparatus according to embodiments.

FIG. **19** is a side view of an apparatus according to an embodiment and an external stimulator.

FIG. **20** is a perspective view of an apparatus according to an embodiment.

FIG. **21** is a perspective view of a portion of an apparatus according to an embodiment.

FIG. **22** is a perspective view of a portion of the apparatus of FIG. **21**.

FIG. **23** is a perspective view of an external stimulator configured for use with the apparatus of FIG. **21**.

FIG. **24** is a perspective view of the apparatus of FIG. **21** and the external stimulator of FIG. **23**.

FIG. **25** is a perspective and partially transparent view of an apparatus according to an embodiment.

FIG. **26** is a perspective view of the apparatus of FIG. **25** and an external stimulator.

FIG. **27** is a perspective view of an apparatus according to an embodiment and an external stimulator.

FIG. **28** is a perspective view of a portion of an apparatus according to an embodiment and an external stimulator.

FIG. **29** is a perspective view of an apparatus according to an embodiment.

FIG. **30** is a perspective view of an apparatus according to an embodiment and an external stimulator.

FIGS. **31-33** are perspective views of apparatus according to embodiments and an external stimulator.

FIG. **34** is a side view of an apparatus according to an embodiment.

FIG. **35** is a top view of the apparatus of FIG. **34**.

FIGS. **36** and **37** are top and bottom perspective views, respectively, of a portion of a stimulator assembly according to an embodiment.

FIG. **38** is a perspective view of the stimulator assembly of FIG. **36** including a battery.

FIG. **39** is an exploded perspective view of a stimulator assembly according to an embodiment.

FIG. **40** is a perspective view of a portion of the stimulator assembly shown in FIG. **42**.

FIG. **41** is a bottom view of the stimulator assembly of FIG. **39**.

FIG. **42** is a top view of the stimulator assembly of FIG. **39** with a portion of the housing removed.

FIG. **43** is an exploded perspective view of a stimulator assembly according to an embodiment.

FIG. **44** is an exploded perspective view of the stimulator assembly of FIG. **43**.

FIG. **45** is a top view of a portion of the stimulator assembly of FIG. **43** in a first configuration.

FIGS. **46-47** are top and bottom views, respectively, of a portion of the stimulator assembly of FIG. **43** in a second configuration.

FIG. **48** is a flow chart of a method of assembling a portion of a stimulator system according to an embodiment.

FIG. **49** is a top view of two experimental apparatus according to embodiments.

FIG. **50** is a cross-sectional view of an apparatus of FIG. **49** taken along line X-X.

FIG. **51** is a front view of an apparatus of FIG. **49** partially immersed in a liquid.

FIG. **52** is a front, cross-sectional view of a portion of a housing according to an embodiment.

FIG. **53** is a perspective, cross-sectional view of a portion of a stimulator assembly according to an embodiment.

FIGS. **54-55** are top views of a stimulator assembly according to an embodiment in a first configuration and a second configuration, respectively.

FIGS. **56-57** are schematic illustrations of a stimulator system according to an embodiment in a first coupled configuration and a second uncoupled configuration, respectively.

FIGS. **58**A-**58**D are front views of stimulator systems according to embodiments disposed on bodily tissue.

FIGS. **59-60** are top views of a stimulator assembly and an electrode assembly, respectively, of a stimulator system according to an embodiment.

FIG. **61** is a side view of the stimulator system of FIGS. **59-60** disposed on bodily tissue and delivering an electrical current to an implanted conductive lead.

## DETAILED DESCRIPTION

Apparatus and methods for transmitting an electrical signal (e.g., a current or stimulation) from an electronic device (e.g., an external stimulator) to a bodily tissue of a patient are described herein. Also described herein are methods for assembling a portion of a stimulator assembly for use in transmitting the electrical signal from the electronic device to the bodily tissue. In some embodiments, an apparatus is configured to be disposed on bodily tissue (e.g., skin) of a patient. The apparatus is configured to receive an electrical input from an external stimulator via a connector and to transmit the electrical input as an electrical current to an electrode disposed on or proximate to the bodily tissue. In this manner, the apparatus transmits the electrical stimulation to the bodily tissue.

As used herein, bodily tissue can include any tissue of a patient suitable for receiving and/or conveying an electrical stimulation. Bodily tissue can include, for example, nervous tissue, such as a nerve, the spinal cord, or another component of the peripheral or central nervous system. In another example, bodily tissue can include muscle tissue, such as, for example, skeletal muscle, smooth muscle, or cardiac muscle. Specifically, bodily tissue can include a group of tissues forming an organ, such as, for example, the skin, lungs, cochlea, heart, bladder, or kidney. In still another example, bodily tissue can include connective tissue, such as, for example, skin, bone or bone-like tissue.

The apparatus is configured to treat a variety of medical conditions, including acute and/or chronic pain, and/or to activate a motor point. For example, the apparatus can be configured to transmit an electrical current that at least partially activates conduction and/or propagation of action potentials (nerve impulses) along the axons of a target nerve associated with a target bodily tissue. In another example, the apparatus can be configured to transmit to the bodily tissue an electrical current that at least partially blocks the conduction and/or propagation of action potentials along the axons of the target nerve associated with the target bodily tissue.

The apparatus can be configured for transcutaneous and/or percutaneous stimulation of the target bodily tissue. In a treatment or procedure for transcutaneous stimulation, for example, the apparatus is configured to transmit an electrical stimulation through bodily tissue from a first electrode positioned on a first location of the patient's skin to a second electrode positioned on a second location on the patient's skin different from the first location. The pathway of the electrical current through the bodily tissue of the patient is a transcutaneous stimulation pathway. In a treatment or procedure for percutaneous stimulation, for example, the apparatus is configured to transmit an electrical stimulation to bodily tissue via an electrical lead. The electrical lead helps direct the electrical current to the target bodily tissue. In some procedures, the electrical lead can be completely implanted within the bodily tissue. In other procedures, the electrical lead is partially implanted within the bodily tissue such that a portion of the lead extends through the skin.

In some embodiments, the apparatus can be a portion of a system for stimulation of the target bodily tissue. For example, in some embodiments, the apparatus includes a substrate and a base, wherein the apparatus is configured for use with an electronic device to deliver an electrical current to the target bodily tissue. In another example, the apparatus includes a housing configured to be disposed about a portion of a stimulator assembly that is configured to transmit an electrical current to the target bodily tissue.

As used in this specification, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, the term "a material" is intended to mean one or more materials, or a combination thereof.

FIG. **1** is a schematic illustration of an apparatus **100** according to an embodiment. The apparatus **100** is configured to transmit an electrical current from a stimulator (not shown) through a bodily tissue of a patient. In this manner, the apparatus **100** is configured to stimulate a target bodily tissue. The apparatus **100** can be, for example, an electrode-battery assembly.

The apparatus **100** is configured to be disposed on or proximate to a patient's body, for example, on the skin of the patient. The apparatus **100** can be coupled to the skin of the patient with an adhesive, a bandage, or the like, or any combination of the foregoing.

The apparatus **100** includes a substrate **102**, a power source **120**, a connector **132**, electrical circuitry **150**, and an electrode assembly **140**. The substrate **102** has a first surface **104** and a second surface **106** different than the first surface **104**. The substrate **102** is configured to be disposed on or proximate to the body of the patient. When the apparatus **100** is disposed on the patient's body, the second surface **106** of the apparatus faces the patient's tissue, e.g., the skin.

The power source **120** is configured to provide power to an external stimulator (not shown) coupled to the apparatus **100**. The power source **120** can be any suitable energy supplying source. For example, in some embodiments, the power source **120** is a battery. In some embodiments, the power source **120** is an ultracapacitor or a supercapacitor. The power source **120** is coupled to the substrate **102**. In the schematic illustration, the power source **120** has a positive terminal **122** and a negative terminal **124**. Each of the positive terminal **122** and the negative terminal **124** are coupled to the substrate **102**.

The connector **132** is configured to electrically couple the external stimulator to the power source **120** and/or the electrical circuitry **150**. The connector **132** can be any suitable mechanism for electrically coupling the external stimulator and the power source **120**. For example, in some embodiments, the connector **132** is configured to provide both a mechanical and an electrical connection between the apparatus **100** and the external stimulator. Said another way, when the external stimulator is mechanically coupled to the apparatus **100** via the connector **132**, the external stimulator is also placed in electrical communication with the power source **120**. The connector **132** can be any suitable connector, including but not limited to, a snap-fit connector. In some embodiments, the connector **132** is a metal electrode. In some embodiments, the connector **132** is configured to provide a wireless electrical connection between the external stimulator and the power source **120**. In some embodiments, for example, the connector is an antenna configured to transmit a signal to and/or receive a signal from the external stimulator. In some embodiments, the connector is a conductive ink, a wire, or the like.

The connector **132** is disposed proximate to the first surface **104** of the substrate **102**. In some embodiments, for example, the connector is embedded in the first surface **104** of the substrate **102**. In some embodiments, the connector **132** is disposed on top of the first surface **104** of the substrate **102**. For example, the connector **132** can be a conductive ink printed onto the first surface **104** substrate. In still other embodiments, a portion of the connector **132** is embedded in the substrate and another portion of the connector extends from the first surface **104**. As illustrated in FIG. **1**, the connector **132** is electrically coupled to at least one of the positive terminal **122** and the negative terminal **124** of the power source **120**.

The electrical circuitry **150** is coupled to the substrate **102**. The electrical circuitry **150** is configured to electrically couple the connector **132** to the at least one of the positive terminal **122** and the negative terminal **124** of the power source **120**. In some embodiments, for example, the electrical circuitry **150** includes a wire configured to electrically connect the connector to the power source **120**. In some embodiments, a portion of the electrical circuitry **150** is a pathway of conductive ink printed onto the substrate **102**.

At least one of the connector **132** or the electrical circuitry **150** is configured to prevent a short circuit of the electrical circuit contained therein. The electrical circuitry **150** can include a variety of suitable mechanisms configured to prevent shorting the electrical circuit (including shorting of the power source **120**). For example, in some embodiments, the electrical circuitry **150** includes a fuse configured to open the electrical circuit in the presence of a threshold electrical load. In some embodiments, the electrical circuitry **150** includes a switch biased towards an open position such that the electrical circuit is incomplete until the switch is moved to a closed position. In some embodiments, the electrical circuitry **150** includes a diode configured to prevent flow of an electrical current in an undesired direction. In some embodiments, the connector **132** is configured as a wireless connector. For example, the connector **132** can be an antenna or a coil configured to wirelessly transmit and/or receive an electrical current between the external stimulator and the power source **120**. In this manner, the connector **132** can be disposed below a surface of the apparatus **100** or otherwise covered such that the connector **132** is isolated from sources of moisture.

The electrode assembly **140** is coupled to the second surface **106** of the substrate **102**. The electrode assembly **140** includes at least one electrode **142**. The electrode **142** is configured to contact bodily tissue. For example, in some embodiments, the apparatus **100** includes a gel electrode **142** configured to adhere to the patient's skin. The electrode **142** is configured to facilitate transmission of an electrical current through the bodily tissue.

FIGS. **2-8** illustrate an apparatus **200** according to an embodiment. The apparatus **200** is configured to be disposed on a tissue (e.g., the skin) of a patient. The apparatus **200** includes a substrate **202**, a power source **220**, a connection assembly **230**, electrical circuitry **250**, and an electrode assembly **240**.

The substrate **202** of the apparatus **200** is a printed circuit board ("PCB"). The PCB **202** has a first surface **204** (see, e.g., FIG. **2**) and a second surface **206** (see, e.g., FIG. **4**). In use, the second surface **206** of the PCB **202** faces the body of the patient and the first surface **204** faces away from the body of the patient. The PCB **202** is flexible such that the PCB can substantially conform to the contours of the portion of the patient's body on which the apparatus **200** is disposed. For example, the PCB **202** can be configured to be flexible such that the PCB conforms to the curvature of a patient's arm, leg, or back. In this manner, the PCB **202** is configured to facilitate positioning and placement of the apparatus **200** on the patient's body.

The power source **220** is configured to provide power to an external stimulator S (see, e.g., FIG. **6**) coupled to the apparatus **200**. The power source **220** is a battery coupled to the PCB **202**. Specifically, the battery **220** is coupled to the PCB **202** by electrically conductive tabs **226**, **228**. As illustrated in FIGS. **2**, **3**A, and **3**B, the battery has a positive terminal **222** and a negative terminal **224**. A first electrically conductive tab **226** is coupled to the positive terminal **222**. A second electrically conductive tab **228** is coupled to the negative terminal **224**. Each of the first and second electrically conductive tabs **226**, **228** are coupled to the PCB **202**. The electrically conductive tabs **226**, **228** can be coupled to the PCB by any suitable coupling mechanism. For example, each electrically conductive tab **226**, **228** can be coupled to the PCB **202** by at least one of a solder joint, a braze joint, a weld, an adhesive, a mechanical coupler, or the like, or any combination of the foregoing. Each of the first and second electrically conductive tabs **226**, **228** provides an electrical connection between its respective positive terminal **222** or negative terminal **224** of the battery **220** and the electrical circuitry **250**, as described in more detail herein.

The connection assembly **230** includes a first connector **232**, a second connector **234**, and a third connector **236**. The connectors **232**, **234**, **236** are disposed proximate to the first surface **204** of the PCB **202**. The first and second connectors **232**, **234**, in conjunction with the electrical circuitry **250**, are configured to electrically couple the battery **220** and the external stimulator S. Specifically, the first connector **232** is electrically coupled to the positive terminal **222** of the battery **220** via the electrical circuitry **250**, and the second connector **234** is electrically coupled to the negative terminal **224** of the battery via the electrical circuitry.

The electrical circuitry **250** is at least partially coupled to the PCB **202**. In some embodiments, at least a portion of the electrical circuitry **250** is a conductive material printed onto the PCB **202**. As illustrated in FIG. **2**, the electrical circuitry **250** includes a first electrical pathway **252**, a second electrical pathway **254**, and a third electrical pathway **256**. The first electrical pathway **252** extends from the first connector **232** to the first electrically conductive tab **226**, which is coupled to the positive terminal **222** of the battery **220**. The first electrical pathway **252** is electrically coupled to the first electrically conductive tab **226**, such as by at least one of a solder, a weld, a braze joint, a conductive adhesive, a mechanical coupler, or the like, or any combination of the foregoing. Thus, the electrical circuitry **250**, via the first electrical pathway **252**, electrically couples the first connector **232** to the positive terminal **222** of the battery **220**.

The second electrical pathway **254** extends from the second connector **234** to the second electrically conductive tab **228**, which is coupled to the negative terminal **224** of the battery **220**. The second electrical pathway **254** is electrically coupled to the second electrically conductive tab, such as by at least one of a solder, weld, braze joint, a conductive adhesive, a mechanical coupler, or the like, or any combination of the foregoing. Thus, the electrical circuitry **250**, via the second electrical pathway **254**, electrically couples the second connector **234** to the negative terminal **224** of the battery **220**. In this manner, when the external stimulator S is coupled to the apparatus **200** via the first and second connectors **232**, **234**, a power circuit is completed between the battery **220** and the external stimulator. When the power circuit is completed, the battery **220** can provide power to the external stimulator S, which the external stimulator can use to generate an electrical current for stimulating bodily tissue, as described in more detail herein.

The connection assembly **230** is configured to prevent a short circuit of the electrical circuit. The connection assembly **230** includes a hydrophobic barrier **218** coupled to the substrate **202**. As illustrated in FIG. **2**, the hydrophobic barrier is a Y-shaped barrier configured to increase impedance of the electrical current between the first connector **232**, second connector **234**, and/or the third connector **236**, for example, when a portion of the substrate is wetted. An experiment testing the impedance of such a barrier is described below with reference to FIGS. **20-22**. In use, the apparatus **200** may be wetted or otherwise exposed to a source of moisture, for example water or perspiration, which can create a leakage path for the electrical current between the first connector **232**, the second connector **234**, and/or the third connector **236** of the connection assembly **230**. Such a leakage path for the electrical current can interfere with delivery of the electrical current intended to stimulate the bodily tissue and/or can cause leakage and discharge of the battery **220**. The hydrophobic barrier **218** increases the impedance between at least one of the connectors **232**, **234**, **236** and another of the connectors **232**, **234**, **236** and/or the wet surface of the substrate **202**. The hydrophobic barrier **218** can be constructed of any suitable material, including, but not limited to, plastic, rubber, glue, or another substantially non-conductive material.

The electrical circuitry **250** is also configured to prevent a short circuit of the electrical circuit. Specifically, as illustrated in FIG. **2**, the electrical circuitry **250** includes a fuse **258** in the second electrical pathway **254**. The fuse **258** is coupled to the PCB **202**. For example, the fuse **258** can be at least partially embedded in the PCB **202**.

The fuse **258** has a closed configuration and an open configuration. When the fuse **258** is in its closed configuration, the electrical circuitry **250** is configured to allow transfer of an electrical current through the circuitry between the battery **220** and the electrically coupled external stimulator S. In other words, the electrical circuit is closed or complete. When the fuse **258** is in an open configuration, a gap or interruption exists in the second electrical pathway **254**. In other words, the electrical circuit is open or incomplete. The transfer of electrical current through the electrical circuitry **250** between the battery **220** and the external stimulator S is inhibited when the circuit is open. As such, the battery **220** is substantially inhibited from providing power to the external stimulator S when the fuse is in its open configuration.

The fuse **258** is configured to be in (or is moved to) its open configuration in the presence of a threshold electrical load. For example, the fuse **258** can be a metal wire or strip configured to melt under an abnormally high electrical load. In another example, the fuse **258** can be configured to break under a threshold electrical load. For example, during use on the body of a patient, the connectors **232**, **234**, **236** of the connection assembly **230** can be exposed when the external stimulator S is not mechanically coupled to the apparatus **200**. The exposed connectors **232**, **234**, **236** create a risk of shorting the battery **220**, for example by exposure to fluid or an electrical charge, which can cause heating and/or explosion of the battery. The fuse **258**, however, is configured to open the electrical circuit in the presence of the threshold electrical load to prevent such a short of the battery.

The electrical circuitry **250** also forms a portion of a stimulation circuit. The stimulation circuit includes the third connector **236**, a portion of the electrical circuitry **250**, such as the third electrical pathway **256**, and the electrode assembly **240**. The stimulation circuit is complete when the external stimulator is coupled to the third connector **236**. The electrical circuitry **250** of the stimulation circuit is configured to receive an electrical current from the external stimulator via the third connector **236**. The electrical circuitry **250** is configured to transmit the electrical current to at least one of a first electrode **242** and a second electrode **244**. The electrical circuitry **250** is also configured to receive at least a portion of the electrical current from at least one of the first electrode **242** and the second electrode **244**. The electrical circuitry **250** transmits the received electrical current to at least one of the external stimulator S or the battery **220**.

The electrode assembly **240** of the apparatus **200** is coupled to the second surface **206** of the PCB **202**, as illustrated in FIG. **4**. The electrode assembly **240** includes the first electrode **242** and the second electrode **244**. As illustrated in FIGS. **7-8**, each of the first electrode **242** and the second electrode **244** is configured to contact bodily tissue T and to facilitate transmission of an electrical current E through the bodily tissue, for example through subcutaneous bodily tissue located below and/or between the first electrode **242** and the second electrode **244**. The first electrode **242** is configured to facilitate transmission of the electrical current E from the external stimulator S through the bodily tissue T. The first electrode **242** can facilitate transmission of the electrical current E to an electrical lead L at least partially implanted within the bodily tissue, as illustrated in FIG. **8**. The second electrode **244** is configured to receive at least a portion of the electrical current E. As illustrated in FIGS. **7-8**, for example, the second electrode **244** can receive electrical current E that has passed through the bodily tissue T and/or through an electrical lead L at least partially implanted within the bodily tissue. The transmission of current to an implanted lead is described, for example, in U.S. patent application Ser. No. 11/337,824, which is incorporated herein by reference in its entirety.

The electrodes **242**, **244** are configured to adhere to bodily tissue (e.g., the skin) of the patient. Each electrode **242**, **244** of the electrode assembly **240** includes a gel on the tissue-facing surface of the electrode. The gel can be any suitable known gel including, but not limited to, wet gels, karaya-gum-based hydrogels, and/or synthetic copolymer-based hydrogels. The first electrode **242** and second electrode **244** can be, for example, a cathodic gel electrode and an anodic gel electrode, respectively.

As illustrated in FIG. **5**, the apparatus **200** can be at least partially enclosed by a material **212**, such as a material configured to increase the comfort of the patient utilizing the apparatus and/or protect components of the apparatus from external elements. The material at least partially encloses at least one of the first surface **204** of the PCB **202**, the battery **220**, and a portion of the electrical circuitry **250**. The material **212** defines an opening **214** through which the connection assembly **230** is accessible. In this manner, the external stimulator S can be physically coupled to the apparatus **200** via the connection assembly **230**, as illustrated in FIG. **6**. The material **212** can be any suitable material including, for example, a foam, a water-proof material, plastic, an insulative material, a non-conductive material, a film, or the like, or any combination of the foregoing.

In use, a target bodily tissue is identified as the target for electrical stimulation. The apparatus **200** is positioned proximate to the identified target bodily tissue, such as on a surface of the patient's skin proximate to a subcutaneous target bodily tissue. For example, the apparatus **200** can be positioned proximate to an arm, leg, back, or other portion of the patient's body. The first and second electrodes **242**, **244** are adhered to the patient's skin in the desired position.

The external stimulator S is placed in electrical communication with the battery **220** of the apparatus **200**. The external stimulator S is electrically coupled to the battery **220** by coupling the external stimulator to the connectors **232**, **234**. The battery **220** provides power to the external stimulator S. In response to receiving power from the battery **220**, the external stimulator S generates an electrical current and transmits the electrical current to the apparatus **200** via at least one connector **232**, **234**, **236**. The electrical current is transmitted via the electrical circuitry **250** to the first electrode **242**. The first electrode **242** transmits at least a portion of the electrical current E through the bodily tissue of the patient, as illustrated in FIG. **7**. In some embodiments, as illustrated in FIG. **8**, a portion of the electrical current E transmitted from the first electrode **242** through the bodily tissue is picked by a proximal end portion of an electrical conductor L (or lead) at least partially implanted within the bodily tissue, as illustrated in FIG. **8**. The electrical conductor L is configured to transmit a portion of the electrical current E from its proximal end portion to a distal end portion of the electrical conductor L. The electrical current E is transmitted from the distal end portion of the electrical conductor L through the bodily tissue T to the second electrode **244**. At least a portion of the electrical current E is received by the second electrode **244**. The electrical circuitry **250** transmits the electrical current E to at least one of the battery **220** or the external stimulator S to complete one cycle of electrical stimulation of the target bodily tissue. The cycle of electrical stimulation of the target bodily tissue is repeated as necessary. The apparatus **200** is disposable and can be removed from the patient and discarded when it is no longer needed or suitable for treatment, such as, for example, when a prescribed course of treatment is completed or when the battery is exhausted.

Although the substrate **202** has been illustrated and described as being a PCB, in other embodiments, the substrate can be constructed of a different material. For example, the substrate can be constructed of silicon, polyamide, or another suitable polymer, or any combination of the foregoing.

Furthermore, although at least a portion of the electrical circuitry **250** and/or the connection assembly **230** has been illustrated and described as being a conductive ink printed on a surface of the substrate **202**, in other embodiments, at least one of the electrical circuitry and the connection assembly can be differently constructed. For example, the connection assembly can include a connector that is a wire, an antenna, a metal electrode, or the like. In another example, at least a portion of electrical circuitry can include or be a wire or another electrically conductive material.

Although the material **212** is illustrated as at least partially enclosing at least one of the first surface **204** of the PCB **202**, the battery **220**, and a portion of the electrical circuitry **250**, in other embodiments, a material can be disposed over a different portion of the apparatus **200**. For example, in some embodiments, the material can be an insulative film disposed over a portion of the electrical circuitry.

Although the apparatus **200** has been illustrated and described as being adhered to the body of the patient via adhesive gel electrodes, in other embodiments, an apparatus can be coupled to the patient with a tape, a strap, a band, a glue, or another adhesive, or any combination of the foregoing. Furthermore, an apparatus that includes a glue, another adhesive, or the like, to adhere to the patient can include the glue, other adhesive, or the like on all or a portion of the portion of the apparatus contacting the body of the patient.

Although the apparatus **200** has been illustrated and described as having a connection assembly **230** including a Y-shaped hydrophobic barrier **218**, in other embodiments, an apparatus can include a barrier having a different configuration. For example, as illustrated in FIG. **9**A, in some embodiments, an apparatus **260** can include a barrier **268**, **269** disposed about at least a portion of at least one connector **264**, **266**. In another example, in some embodiments, as illustrated in FIG. **9**B, an apparatus **270** can include a plurality of barriers **278**, **279** positioned at least on opposing sides of at least one connector **274**. In still another example, as illustrated in FIG. **9**C, in some embodiments, an apparatus can include a non-Y-shaped barrier **288** positioned between at least a first connector **284** and a second connector **286**.

FIG. **10** is an illustration of an apparatus **300** according to an embodiment. The apparatus **300** is configured to transmit an electrical current from an external stimulator $S_2$ to a target bodily tissue. The apparatus includes a substrate **302**, a power source **320**, a connection assembly **330** including three connectors **332**, **334**, **336**, electrical circuitry **350** including a fuse **358**, and an electrode assembly **340**.

The substrate **302** includes a first layer **308** having a first surface **304** and a second layer **310** having a second surface **306** different than the first surface. As illustrated in FIG. **10**, each of the power source **320**, the connectors **332**, **334**, **336**, and the electrical circuitry **350** is at least partially embedded in the first layer **308** of the substrate **302**. The first layer **308** of the substrate is formed of a first material. The second layer **310** of the substrate is formed over a portion of the electrode assembly **350**. The second layer **310** of the substrate is formed of a second material different than the first material.

As illustrated in FIG. **10**, the apparatus **300** includes a magnet **366** coupled to the substrate **302**. The magnet **366** is configured to move a switch in the external stimulator from a first position in which the switch is electrically coupled to a first output channel to a second position in which the switch is electrically coupled to a second output channel different than the first output channel. For example, as illustrated in FIG. **10**, movement of the magnet **366** from its first position can move the switch from a first position in which the switch is coupled to a high output channel (indicated as ChH) to a second position in which the switch is coupled to a low output channel (indicated as ChL). In this manner, the magnet **366** can be used to control an amount of electrical current output from the external stimulator $S_2$ to the apparatus **300**.

Although the apparatus **200**, **300** have been illustrated and described as including at first electrode **242**, **342** and a second electrode **244**, **344** disposed on a second surface **206**, **306** of a substrate **202**, **302** and configured to facilitate transmission of an electrical current from an external stimulator S, $S_2$ through the bodily tissue, in some embodiments, an apparatus is configured to deliver or transmit the electrical current to the bodily tissue in a different manner. For example, as illustrated in FIG. **11**, an apparatus **400** according to an embodiment is an electrode-battery assembly configured for percutaneous delivery of an electrical current to target bodily tissue.

The electrode-battery assembly **400** includes a substrate **402**, a battery **420**, a connection assembly **430**, electrical circuitry **450**, and an electrode assembly **440**. The substrate **402** has a first layer **408** and a second layer **410**. The battery **420**, and electrical circuitry **450** are at least partially embedded in the first layer **408** of the substrate. The electrical circuitry **450** includes a fuse **458** configured to open the electrical circuit in the presence of a threshold electrical load, as described above.

An external stimulator $S_3$ is electrically coupled to the electrode-battery assembly **400** via the connection assembly **430**. The connection assembly **430** includes a first connector **432**, a second connector **434**, a third connector **436**, and a fourth connector **438**. The connectors **432**, **434**, **436**, **438** of the connection assembly **430** extend from a surface of the first layer **408** of the substrate **402**.

The third connector **436** is configured to receive an electrical current input from the external stimulator $S_3$. The third connector **436** is configured to transmit the electrical current via a first electrical pathway **452** of the electrical circuitry **450** to the fourth connector **438**. The fourth connector **438** is physically and electrically coupled to an electrode **446** of the electrode assembly **440** via a second electrical pathway **454**. For example, as illustrated in FIG. **11**, the fourth connector **438** is coupled to the second electrical pathway **454** including an electrical conductor exterior to the substrate **402** and extending from the fourth connector **438** to the electrode **446** implanted within the bodily tissue T.

The electrode assembly **440** includes a first electrode **442**, a second electrode **444**, and a third electrode **446**. The first electrode **442** and second electrode **444** are coupled to the second layer **410** of the substrate **402**. The third electrode **446** is coupled to the substrate **402** via the second electrical pathway **454** and is configured to be at least partially implanted within the bodily tissue T. At least the third electrode **446** is configured to transmit an electrical current from the external stimulator $S_3$ to the bodily tissue T. In use, the external stimulator $S_3$ transmits an electrical current to the third connector **436**. The electrical current is transmitted from the third connector **436** via the first electrical pathway **452** to the fourth connector **438**, and from the fourth connector via the second electrical pathway **454** to the third electrode **446**. The third electrode **446** transmits at least a portion of the electrical current E to the bodily tissue, as illustrated in FIG. **11**. The second electrode **444** is configured to receive at least a portion of the electrical current from the bodily tissue.

The electrode-battery assembly **400** is configured to receive an electrical current from the external stimulator $S_3$ via at least one of a first output channel and a second output channel of the external stimulator. For example, as illustrated in FIG. **11**, the external stimulator $S_3$ has a high output channel ChH and a low output channel ChL. The electrode-battery assembly **400** is illustrated in FIG. **11** as being electrically coupled to the low output channel ChL of the external stimulator $S_3$ via the third connector **436**, however, in use, a patient or practitioner operating the stimulator can selectively electrically couple the electrode-battery assembly to the high output channel ChH via the third connector.

The external stimulator $S_3$ can be wirelessly controlled by the operator. For example, the operator can wirelessly control the external stimulator $S_3$ using a remote control R to communicate with the stimulator over a radio frequency. In this manner, the operator can wirelessly program the external stimulator $S_3$, power on and/or off the external stimulator $S_3$, and/or select the desired output channel (e.g., ChH and/or ChL). In some embodiments, for example, the remote control R can a dedicated programming device for use specifically with the stimulation system. In other embodiments, however, the remote control R can be a personal digital assistant (PDA) or other hand-held computing device that is configured to communicate with the external stimulator $S_3$. Such a PDA or hand-held computing device can include, for example, a Central Processing Unit (CPU) and electronic memory, and can be generally used for storing and organizing information and for providing tools for everyday tasks. In such embodiments, the system can include an adaptor and/or cradle (not shown) configured to be coupled to and/or receive the PDA. The adaptor and/or cradle can enable the PDA to communicate with the external stimulator $S_3$ such that external stimulator $S_3$ can be wirelessly controlled by the operator, patient or other user. Although described as including an adaptor and/or cradle, in other embodiments, the external stimulator $S_3$ can be wirelessly controlled using a PDA and/or hand-held computing device without the need for an adaptor and/or cradle.

Although the apparatus **400** is illustrated and described as percutaneously transmitting the electrical current, in some embodiments, an apparatus is configured for both transcutaneous and percutaneous transmission of the electrical current. For example, an apparatus can be configured to transcutaneously transmit the electrical current through bodily tissue from a first electrode disposed on a surface of the patient's skin and percutaneously transmit the electrical current via a second electrode (e.g., similar to electrode **446** described above) at least partially implanted in the bodily tissue. In some embodiments, the high output channel ChH of the external stimulator is configured for transcutaneous stimulation and the low output channel ChL is configured for percutaneous stimulation of the target bodily tissue. Electrical current from each of the first electrode and the second electrode can be received by a third electrode disposed on the skin of the patient, similar to electrode **444** described above.

Although the apparatus **200**, **300**, **400** described above have been illustrated and described as including a fuse **258**, **358**, **458** configured to open the electrical circuit, in other embodiments, an apparatus **500** includes electrical circuitry differently configured to prevent a short circuit of the electrical circuit, as illustrated in FIG. **12**. The apparatus **500** is configured to transmit an electrical stimulation to a bodily tissue and includes a substrate **502**, an electrode assembly **540**, a power source **520**, and a connection assembly **530**.

The substrate **502** has a first surface **504** and a second surface **506** different than the first surface. The power source **520** is coupled to the substrate **502** and can be any suitable source of power described herein. The power source **520** has a positive terminal **522** and a negative terminal **524**. The power source **520** is configured to provide power to an external stimulator $S_4$, for example, when the external stimulator is in electrical communication with the power source.

The electrode assembly **540** is coupled to the second surface **506** of the substrate **502**. The electrode assembly **540** is configured to facilitate transmission of an electrical current from the external stimulator $S_4$ through the bodily tissue. The electrode assembly includes a first electrode **542** and a second electrode **544** different than the first electrode.

The connection assembly **530** is coupled to the substrate **502** and includes up to two connectors configured to be in electrical communication with the external stimulator $S_4$. Specifically, as illustrated in FIG. **12**, the connection assembly **530** includes a first connector **532** and a second connector **534**. Each of the first connector **532** and a second connector **534** is coupled to the first surface **504** of the substrate **502**. The first connector **532** is configured to electrically couple the external stimulator $S_4$ to the positive terminal **522** of the power source **520** and to the first electrode **542**. The second connector **534** is configured to electrically couple the external stimulator $S_4$ to the negative terminal **524** of the power source **520** and to the second electrode **544**.

The connection assembly **530** has a first configuration in which the two connectors **532**, **534** are electrically coupled to the external stimulator $S_4$ (as illustrated in FIG. **12**) and a second configuration in which the two connectors are electrically isolated from the external stimulator (not shown). When the connection assembly **530** is in its first configuration, the connection assembly completes a power circuit between the power source **520** and the external stimulator $S_4$ and a stimulation circuit between the external stimulator and the electrode assembly **540**, as described in more detail herein.

The power circuit includes electrical circuitry **550**, a diode **562**, the connection assembly **530**, and the power source **520**. As illustrated in FIG. **12**, the electrical circuitry **550** includes a first electrical pathway **552** and a second electrical pathway **554**, each coupled to the substrate **502**. The first electrical pathway **552** electrically couples the first connector **532** to the positive terminal **522** of the power source **520**. The second electrical pathway **554** electrically couples the second connector **534** to the negative terminal **524** of the power source **520**. When the connection assembly **530** is in its second configuration, the power circuit is open (or incomplete). When the connection assembly **530** is in its first configuration such that the first and second connectors **532**, **534**, respectively, are electrically coupled to the external stimulator $S_4$, the power circuit is closed (or complete) and the power source **520** provides power to the external stimulator.

The diode **562** is coupled to the substrate **502** and is disposed within the first electrical pathway **552**. The diode **562** is configured to allow electrical current to flow in a first direction and to substantially inhibit flow of the electrical current in a second direction different than the first direction. As illustrated in FIG. **12**, the diode **562** is configured to allow flow of the electrical current from the power source in a first direction towards the first electrode **542** via the first electrical pathway **552**. The diode **562** is configured to substantially inhibit flow of the electrical current in a second direction opposite the first direction, such as from the first connector **532** to the power source **520** and/or to the second electrode **544** via the first electrical pathway **552**. In this manner, the diode **562** is configured to prevent a short circuit of the electrical circuit because the stimulating electrical current transmitted from the external stimulator $S_4$ to the first connector **532** is substantially inhibited from flowing to the power source **520**, which otherwise may cause the power source to overheat, explode, or otherwise become defective.

The stimulation circuit includes electrical circuitry **550**, a capacitor **564**, the connection assembly **530**, and the electrode assembly **540**. As illustrated in FIG. **12**, the electrical circuitry **550** includes a third electrical pathway **556** coupled to the substrate **502**. The third electrical pathway **556** electrically couples the first connector **532** to the first electrode **542** of the electrode assembly **540**. The second electrical pathway **554** electrically couples the second connector **534** to the second electrode **544**. As such, the negative terminal **524** of the power source **520** is also coupled to the second electrode **544**.

The capacitor **564** is coupled to the substrate **502** and is disposed in the electrical circuitry **550**, for example, in the third electrical pathway **556** as illustrated in FIG. **12**. The capacitor **564** is configured to separate an alternating current from a direct current. The capacitor **564** is configured to substantially inhibit flow of the direct current from the power source **520** to the first electrode **542**. The capacitor **564** is configured to deliver at least one of the alternating current and the direct current from the external stimulator to the first electrode.

When the connection assembly **530** is in its first configuration (and the power circuit is closed, as described above), the stimulation circuit is also closed and an electrical current can be transmitted from the external stimulator through the target bodily tissue via the apparatus **500**. Specifically, the electrical current is transmitted from the external stimulator $S_4$ to the first connector **532**. The first connector **532** transmits the electrical current towards the first electrode **542** via the third electrical pathway **556**. The capacitor **564** separates direct current from alternating current, and then transmits at least one of the direct current or the alternating current to the first electrode **542**. The first electrode **542** transmits the electrical current through the bodily tissue T. The second electrode **544** receives at least a portion of the electrical current from the bodily tissue T and transmits the electrical current to the electrical circuitry **550** of the apparatus **500**.

Although the diode **562** has been illustrated and described as being configured to allow flow of the electrical current from the power source **520** in a first direction towards the first electrode **542** and to substantially inhibit flow of the electrical current in a second direction opposite the first direction, such as from the first connector **532** to the power source **520** and/or to the second electrode **544** via the first electrical pathway **552**, in some embodiments, the diode **562** is configured to allow flow of the electrical current in the second direction and to substantially inhibit flow of the electrical current in the first direction.

Although the apparatus **500** has been illustrated and described as being electrically coupled to the external stimulator via the two mechanical connectors **532**, **534**, in some embodiments, an apparatus is electrically coupled to the external stimulator in a different manner. For example, as illustrated in FIG. **13**, in some embodiments, an apparatus **600** is wirelessly electrically coupled to an external stimulator $S_5$.

The apparatus **600** includes a substrate **602** configured to be positioned on or proximate to the bodily tissue T. The substrate **602** has a first surface **604** and a second surface **606** different than the first surface. The second surface **606** of the substrate is configured to face the bodily tissue and the first surface **604** is configured to face away from the bodily tissue when the apparatus is positioned on or proximate to the bodily tissue. A power source **620** is coupled to the substrate **602**. As illustrated in FIG. **13**, the power source **620** is at least partially embedded in the substrate **602**.

The apparatus **600** includes a connection assembly **630** configured to be in electrical communication with an external stimulator $S_5$. The connection assembly **630** includes a first connector **632** and a second connector **634**. Each of the first connector **632** and the second connector **634** is an antenna configured as a first coil **614** and a second coil **616**, respectively, that is configured to be in wireless electrical communication with the external stimulator $S_5$. The first coil **614** and second coil **616** are each coupled to the first surface **604** of the substrate **602**. Specifically, the coils **614**, **616** are embedded in the substrate **602**. In this manner, the coils **614**, **616** are configured to prevent a short circuit of the electrical circuit, for example, by substantially preventing exposure of the coils to a fluid.

The connection assembly **630** has a first configuration in which the coils **614**, **616** are electrically coupled to the external stimulator $S_5$ and a second configuration in which the coils are electrically isolated from the external stimulator. The connection assembly **630** is configured to complete a power circuit between the power source **620** and the external stimulator $S_5$ and a stimulation circuit between the external stimulator and an electrode assembly **640**, as described in more detail herein.

As illustrated in FIG. **13**, the power circuit includes the first coil **614**, the power source **620**, an oscillator **638**, and electrical circuitry **650**. The electrical circuitry **650** includes a switch **660** disposed in a first electrical pathway **652**. The switch **660** can be any suitable switch for opening and closing a circuit. For example, the switch **660** can be a reed switch including a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope (not shown). The switch **660** has an open configuration (see, e.g., FIG. **13**) and a closed configuration. In its open configuration, the pair of contacts of the reeds is open (or separate). Thus, the electrical circuit is open when the switch is in its open configuration. The switch **660** is movable to its closed configuration by the introduction of a magnetic field, such as by placing a magnet M in the external stimulator $S_5$ proximate to the switch. Specifically, the presence of the magnetic field causes the pair of contacts to close or otherwise come together. As such, the switch **660** is configured to close the electrical circuit when the switch is moved to its closed configuration. The switch **660** is biased to its open configuration. In this manner, the electrical circuitry is configured to prevent a short circuit of the electrical circuit.

The power source **620** is configured to transmit an electrical current to the electrical circuitry **650** when the connection assembly **630** is in its first configuration and the switch **660** is in its closed configuration. The electrical circuitry **650** is configured to transmit the electrical current to the oscillator **638**. The oscillator **638** is configured to deliver at least one oscillation (of electrical current) to the first coil **614** to initiate wireless transmission of an electrical output from the first coil to the external stimulator $S_5$. The first coil **614** is configured to wirelessly transmit the electrical output to the external stimulator $S_5$, such as to a coil $C_1$. The coil $C_1$ of the external stimulator $S_5$ can transmit the electrical current to a source of power $P_1$ disposed within the external stimulator. The source of power $P_1$ can transmit the electrical current to a stimulation circuit and/or a radio frequency circuit coupled to the external stimulator $S_5$. For example, the source of power $P_1$ can transmit the electrical current to a portion of the stimulation circuit $P_2$ disposed on the external stimulator $S_5$.

As illustrated in FIG. **13**, the stimulation circuit includes the second coil **616**, electrical circuitry **650**, and an electrode assembly **640**. The second coil **616** is disposed proximate to the first surface **604** of the substrate **602**. Specifically, the second coil **616** is embedded in the substrate **602** proximate the first surface **604**. The second coil **616** is configured for wireless electrical communication between an electrode of the electrode assembly **640** and the external stimulator $S_5$. For example, the second coil **616** is configured to receive an electrical input from a coil $C_2$ of the external stimulator $S_5$ and to transmit at least a portion of the electrical input (or current) to the electrical circuitry **650**.

The electrical circuitry **650** is configured to transmit the electrical current to the electrode assembly, for example, via a second electrical pathway **654**. The electrode assembly **640** is coupled to the second surface **606** of the substrate **602** and includes a first electrode **642** and a second electrode **644** different than the first electrode. The first electrode **642** is coupled to the second electrical pathway **654** of the electrical circuitry **650**. The first electrode **642** can receive an electrical current from the electrical circuitry **650** via the second electrical pathway **654** and can facilitate transmission of the electrical current through the bodily tissue. The second electrode **644** is configured to receive a portion of the electrical current from the bodily tissue. The second electrode **644** is configured to transmit the electrical current to the electrical circuitry **650**, such as to a third electrical pathway **656**. The electrical circuitry **650** can transmit the electrical current to the second coil **616**. The second coil **616** can wirelessly transmit an electrical output to the external stimulator $S_5$.

Although the apparatus **600** is illustrated and described as being in wireless communication with the external stimulator $S_5$ via a connection assembly **630** including the first and second coils **614**, **616**, respectively, in some embodiments, an apparatus is in wireless communication with an external stimulator via a connection assembly having a different configuration. For example, in some embodiments, an apparatus includes at least one antenna configured to wirelessly communicate with an external stimulator.

As illustrated in FIG. **14**, an apparatus **700** includes a connection assembly **730** having a plurality of connectors that includes a first connector **732**, a second connector **734**, and a third connector **736**. The connection assembly **730** is disposed proximate to a first surface **704** of a substrate **702**. Each of the first connector **732**, second connector **734**, and third connector **736** is configured to be coupled to a counterpart connector (not shown) on the stimulator $S_6$. The first connector **732** is configured to be in electrical communication with a battery **720** coupled to the substrate **702** via a first electrical pathway **752** of electrical circuitry **750**. The first electrical pathway **752** includes a first switch **712**. The second connector **734** is configured to be in electrical communication with the battery **720** via a second electrical pathway **754**. The second connector **734** is also configured to be in electrical communication with a first electrode **744** of an electrode assembly **740** coupled to the substrate **702** via the second electrical pathway **754**. The electrode assembly **740** can be coupled, for example, to a second surface **706** of the substrate **702**. The second electrical pathway **754** includes a second switch **714**. The third connector **736** is configured to be in electrical communication with a second electrode **742** of the electrode assembly **740** via a third electrical pathway **756**. The third electrical pathway **756** includes a third switch **716**. Each switch **712**, **714**, **716** is configured to move from an open configuration to a closed configuration in the presence of a magnetic field. For example, as illustrated in FIG. **14**, each switch **712**, **714**, **716** is configured to move to its respective closed configuration by a magnet $M_2$ coupled to the external stimulator $S_6$. When the switches **712**, **714**, **716** are each in the closed configuration, and the external stimulator $S_6$ is in electrical communication with the connection assembly **730**, the electrical circuit is complete (or closed).

When the electrical circuit is complete, the battery **720** is configured to provide power to the external stimulator $S_6$. Power from the battery **720** enables the external stimulator to generate an electrical output to be received as an electrical input by the third connector **736**. The second electrode **742** is configured to receive the electrical current from the third connector **736** via the third electrical pathway **756**. The second electrode **742** is configured to transmit the electrical current through target bodily tissue T. The first electrode **744** is configured to receive at least a portion of the electrical current from the bodily tissue T and to transmit the electrical current to the external stimulator $S_6$ via the second electrical pathway **754**.

Although the apparatus **600**, **700** have been illustrated and described as including two antenna coils **614**, **616** and three connectors **732**, **734**, **736**, respectively, in other embodiments an apparatus can include any suitable combination of connectors, e.g., wired and/or wireless, for electrical communication with an external stimulator.

In some embodiments, as illustrated in FIG. **15**, an apparatus **760** includes a planar dipole antenna **764** that is printed onto a substrate **762**, such as a PCB. The antenna **764** includes a first connector **766**, a first branch **767**, a second connector **768**, and a second branch **769**. The first connector **766** is configured to be in electrical communication with an external stimulator (not shown). The first branch **767** is configured to electrically couple the first connector **766** to electrical circuitry (not shown) coupled to the substrate **762**. The second connector **768** is configured to be in electrical communication with the external stimulator. The second branch **769** is configured to electrically couple the second connector **768** to the electrical circuitry.

In some embodiments, as illustrated in FIG. **16**, an apparatus **770** includes a planar folded dipole antenna coupled to a substrate **772**. The antenna **774** includes a first connector **776**, a first branch **777**, a second connector **778**, and a second branch **779**. The first connector **776** is configured to be in electrical communication with an external stimulator (not shown). The first branch **777** is configured to electrically couple the first connector **776** to electrical circuitry (not shown) coupled to the substrate **772**. The second connector **778** is configured to be in electrical communication with the external stimulator. The second branch **779** is configured to electrically couple the second connector **778** to the electrical circuitry.

In yet another example, in some embodiments, as illustrated in FIG. **17**, an apparatus **780** includes a planar non-symmetrical dipole antenna **784**, which may also be referred to as a monopole antenna, coupled to a substrate **782**. The antenna **784** includes a first connector **786** and a branch **787**. The first connector **786** is configured to be in electrical communication with an external stimulator (not shown). The branch **787** is configured to electrically couple the first connector **786** and electrical circuitry (not shown) coupled to the substrate **782**. The branch **787** can be coupled to a power source **785**. The antenna **764** includes a second connector **788** configured to be in electrical communication with the external stimulator.

In still another example, in some embodiments, as illustrated in FIG. **18**, an apparatus **790** includes a planar spiral antenna **794** coupled to a substrate **792**, such as a PCB. The antenna **794** includes a first connector **796**, a second connector **798**, and an electrical pathway **797**. Each of the first connector **796** and the second connector **798** is configured to be in electrical communication with an external stimulator (not shown). The electrical pathway **797** electrically couples the first connector **796** to the second connector **798**. The electrical pathway **797** is configured as a spiral at least partially printed on a first surface **793** of the PCB **792**. In some embodiments, a return electrical pathway (not shown) can be at least partially printed on an opposing surface (not shown) of the PCB **792**. In some embodiments, a return electrical pathway can be at least partially printed on an inner layer of a multi-layered PCB.

Although the apparatus **200**, **300**, **400**, **500**, **600**, **700** have been illustrated and described as including a power source (or battery) **220**, **320**, **420**, **520**, **620**, **720**, respectively, coupled to a substrate **202**, **302**, **402**, **502**, **602**, **702**, respectively, in some embodiments, an apparatus includes a power source that is the substrate.

For example, as illustrated in FIG. **19**, an apparatus **800** includes a flexible battery **820** having a first surface **804** and a second surface **806**. The flexible battery **820** is configured to provide power to an external stimulator $S_7$ coupled the flexible battery **820**. The external stimulator $S_7$ can be coupled to the flexible battery by any coupling mechanism described herein that puts the external stimulator in electrical communication with the apparatus **800**. For example, as illustrated in FIG. **19**, the apparatus **800** includes a connection assembly **830** coupled to the first surface of the flexible battery **820**. The connection assembly **830** is configured to complete a power circuit between the flexible battery **820** and the external stimulator $S_7$ and a stimulation circuit between the external stimulator an at least one electrode. The connection assembly **830** includes a first connector **832** and a second connector **834**. Each connector **832**, **834** is configured to electrically couple the flexible battery **820** to the external stimulator $S_7$. The first connector **832** is configured to electrically couple the external stimulator $S_7$ to a first electrode **842** of an electrode assembly **840** via electrical circuitry **850**. The second connector **834** is configured to electrically couple the external stimulator $S_7$ to a second electrode **844** of the electrode assembly via the electrical circuitry **850**. The electrode assembly **840** is coupled directly to the second surface **806** of the flexible battery **820**. Each of the first electrode **842** and the second electrode **844** is configured to contact a bodily tissue.

In use, when the external stimulator $S_7$ is electrically coupled to the flexible battery **820**, the flexible battery provides power to the external stimulator. The external stimulator $S_7$ transmits an electrical output to the first connector **832**. The first connector **832** transmits the electrical input as an electrical current to the first electrode **842** via a first electrical pathway **852**. The first electrode **842** transmits the electrical current through the bodily tissue to stimulate at least a portion of the bodily tissue. The second electrode **844** receives a portion of the electrical current from the bodily tissue. The second electrode **844** transmits the electrical current to the second connector **834** via a second electrical pathway **854**. The second connector **834** transmits an electrical output to the external stimulator $S_7$.

The flexible battery **820** can be biodegradable. In some embodiments, for example, the flexible battery **820** can include a plurality of carbon nanotubes, cellulose disposed between at least a portion of a first carbon nanotube and a second carbon nanotube, an electrolyte, and/or a metal foil of lithium and ion.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Elements of each embodiment described herein may be combined in any suitable manner with one or more elements of another embodiment described herein. Where methods described above indicate certain events occurring in certain order, the ordering of certain events may be modified. Additionally, certain of the events may be performed concurrently in a parallel process when possible, as well as performed sequentially as described above.

For example, although apparatus **200** is illustrated and described as including a fuse **258**, in some embodiments, an apparatus similar to apparatus **200** may include a switch similar to switch **660** in addition to or instead of a fuse.

Although an apparatus has been illustrated and described herein as including one switch or three switches, in other embodiments, an apparatus can include any suitable number of switches, such as two, four, or more switches.

Although a switch has been illustrated and described herein as being in an open configuration in the absence of a magnetic field and as being in a closed configuration in the presence of a magnetic field, in other embodiments, the switch can be differently configured. For example, in some embodiments, a switch can be configured to be in a closed configuration in the absence of a magnetic field and an open configuration in the presence of a magnetic field.

In another example, although an apparatus has been illustrated and described herein as having mechanical connectors for connection to the external stimulator, in other embodiments, such an apparatus can include a wireless connector.

In still another example, although the apparatus have been illustrated and described as including two electrodes, in other embodiments, an apparatus can include any suitable number of electrodes. For example, in some embodiments, an apparatus includes a first cathodic electrode and a plurality of anodic electrodes. The plurality of anodic electrodes can include two, three, four, or more electrodes. Each electrode of the plurality of anodic electrodes can be selectively positioned at a desired location on the body of the patient, such as at spaced locations to help direct an electrical current from the cathodic electrode through a greater area of bodily tissue. In other embodiments, for example, an apparatus can include a first anodic electrode and a plurality of cathodic electrodes. The plurality of cathodic electrodes can transmit a plurality of electrical currents through the bodily tissue to the anodic electrode. In still other embodiments, an apparatus can include a plurality of cathodic electrodes and a plurality of cathodic electrodes.

Although the apparatus have been illustrated and described as including a substrate having a length and a width greater than a length of a first diameter of the power source and a width of a second diameter of the power source, in other embodiments, an apparatus includes a substrate having a different configuration. For example, as illustrated in FIG. **20**, an apparatus **301** can include a substrate **303** that has a first portion **305** having a width $W_1$ equal to or greater than a diameter D of the power source **321** and a second portion **307** having a width $W_2$ less than the width $W_1$ of the first portion **305** of the substrate **303**.

In yet another example, although the connectors **232**, **234**, **236** of apparatus **200** have been illustrated and described as having a vertical orientation, in other embodiments, an apparatus can include at least one connector having a different orientation. For example, as illustrated in FIGS. **21-24**, an apparatus **900** includes a substrate **902**, a power source **920**, a connection assembly **930**, electronic circuitry **950**, an electrode assembly **940**, and a coupling mechanism **912** (not shown in FIGS. **21** and **22** for clarity of illustration purposes).

The connection assembly **930** includes connectors **932**, **934**, **936**, **938**. Each of the connectors **932**, **934**, **936**, and **938** has a horizontal orientation. In other words, each of the connectors **932**, **934**, **936**, and **938** has an orientation that is substantially parallel to a portion of the substrate **902**. In this manner, the external stimulator $S_8$ is moved laterally to engage and/or disengage with the connectors **932**, **934**, **936**, **938** of the apparatus **900**.

The connectors **932**, **934**, **936**, **938** are electrically coupled to an electrical pathway **952**, **954**, **956**, **958**, respectively, of the electronic circuitry **950**. The connectors **932**, **934**, **936**, **938** are configured to electrically couple the electronic circuitry **950** to the external stimulator $S_8$ by being coupled to a counterpart connector $R_1$, $R_2$, $R_3$, $R_4$, respectively, of the external stimulator $S_8$ (see, e.g., FIG. **23**).

The coupling mechanism **912** is configured to couple the external stimulator $S_8$ to the apparatus **900**. As illustrated in FIG. **24**, the coupling mechanism **912** is configured to engage a portion of the external stimulator $S_8$. For example, the external stimulator $S_8$ can define a groove or recess configured to receive a portion of the first member of the apparatus **900**. Although the apparatus **900** is illustrated as having the connection assembly **930** coupled to an end of the external stimulator $S_8$ and the coupling mechanism **912** engaged with an opposite end of the external stimulator $S_8$, in other embodiments, the connection assembly and/or the coupling mechanism can engage a different portion of the external stimulator $S_8$.

Additionally, although apparatus **200** is shown and described herein as including a power source **220** that is coupled to the PCB **202** by electrically conductive tabs **226**, **228**, in other embodiments, the power source can be electrically coupled to the substrate in any suitable manner. For example, as illustrated in FIGS. **21-22**, a portion **903** of the substrate **902** can be folded or otherwise disposed about a portion of the power source **920**. As also illustrated in FIG. **22**, a portion of the electrical pathway **954** can be disposed on the portion **903** of the substrate **902** that is folded or otherwise disposed about the portion of the power source **920**. When the portion **903** of the substrate **902** is folded about the power source **920**, the portion of the electrical pathway **954** contacts the power source **920**. In this manner, a terminal of the power source **920** can be electrically coupled to the PCB **202** by the electrical pathway **954**.

In some embodiments, as illustrated in FIGS. **25** and **26**, an apparatus **901** includes a housing **913**. The housing **913** is configured to at least partially enclose components (e.g., as shown dashed lines in FIG. **25**) of the apparatus **901**, such as, but not limited to, a power source, electronic circuitry, a substrate, or the like. The housing **913** defines a perimeter **915** and a recess **917** within the perimeter **915**. The recess **917** is configured to at least partially receive an external stimulator $S_9$, as illustrated in FIG. **26**. A coupling mechanism **909** (a portion of which is shown in dashed lines in FIG. **25**) is configured to removably couple the external stimulator $S_9$ to the housing **913**. The coupling mechanism **909** is coupled to the housing **913** and includes a protrusion **911**. The protrusion **911** is configured to engage the external stimulator $S_9$ when the external stimulator $S_9$ is at least partially received in the recess **917**. The protrusion **911** is configured to release the external stimulator $S_9$ when the protrusion **911** is pushed, depressed, or otherwise moved by the operator (e.g., a physician or the patient). In some embodiments, the protrusion **911** is configured to move the external stimulator $S_9$ in a direction away from the recess **917** when the protrusion **911** is pressed or moved by the operator.

Although the apparatus **900** is illustrated and described herein as including four horizontally oriented connectors **932**, **934**, **936**, **938** configured to be coupled to the external stimulator $S_8$, in other embodiments, an apparatus **921**, **931** can be configured to receive a horizontal protrusion of a external stimulator $S_{10}$, $S_{11}$, respectively, as illustrated in FIGS. **27** and **28**.

In another embodiment, as illustrated in FIG. **29**, an apparatus **941** includes a receiving portion **943** configured to receive a portion of an external stimulator $S_{12}$ (not shown) and a protrusion **945** configured to engage an outer surface of the external stimulator $S_{12}$. In still another embodiment, an apparatus **951** is configured to be coupled to an external stimulator $S_{12}$ without such a protrusion, as illustrated in FIG. **30**.

Although the apparatus **901** has been illustrated and described herein as including a housing **913** having a certain outer shape and/or profile, in other embodiments, an apparatus can have a different outer shape and/or profile. For example, an apparatus can include a housing having an outer shape and/or profile like that of apparatus **961**, **971**, and/or **981**, as illustrated in FIGS. **31-33**.

Although various embodiments for transmitting an electrical current or stimulation from an electronic device or stimulator to a bodily tissue have been described herein, additional embodiments are contemplated. For example, FIGS. **34-35** show a portion **170** of a stimulation system according to an embodiment. The stimulation system can be any of the stimulation systems shown and described herein, and is configured to transmit an electrical signal or stimulus from a detachable electronic device (not shown) to a bodily tissue of a patient. The portion **170** of the stimulation system can be, for example, a portion of an electrode-battery assembly. In another example, the portion **170** of the stimulation system can be a portion of an electrode base assembly.

The portion **170** of the stimulation system includes a base **172** and a substrate **180**. The base **172** is substantially rigid. An object with substantial rigidity can be characterized as having resistance to deflection and/or deformation in the presence of an external force (e.g., a bending force). The rigidity of an object is an extensive property of the object being described, and thus is dependent upon the material from which the object is formed and certain physical characteristics of the object (e.g., shape and boundary conditions). For example, the rigidity of an object can be increased or decreased by constructing the object from a material having a high modulus of elasticity. The modulus of elasticity is an intensive property of the constituent material and describes an object's tendency to elastically (i.e., non-permanently) deform in response to an applied force. In another example, the rigidity of the object can be increased or decreased by changing the flexural modulus of a material of which the object is constructed. Flexural modulus is used to describe the ratio of the applied stress on an object in flexure to the corresponding strain in the outermost portions of the object. The flexural modulus, rather than the modulus of elasticity, is used to characterize certain materials, for example plastics, that do not have material properties that are substantially linear over a range of conditions. In some embodiments, the base **172** can be constructed from a material having a flexural modulus of at least 750,000 p.s.i.

The base **172** includes a first protrusion **174** and a second protrusion **176**. The base **172** is configured to be coupled to the electronic device (not shown in FIGS. **34** and **35**). For example, the base **172** can receive at least a portion of the electronic device within the region **175** between the first protrusion **174** and the second protrusion **176**. At least one of the first protrusion **174** and the second protrusion **176** can be configured to engage the electronic device when the portion of the electronic device is received by the base **172** (e.g., in a similar manner as described above with respect to protrusion **911** of apparatus **901**). The electronic device can be any suitable device including, for example, a stimulator, an external pulse generator, or other electronic device shown and described herein.

The substrate **180** is flexible and is coupled to the base **172**. Similarly stated, the substrate **180** has a low resistance to deflection, deformation and/or displacement when exposed to an external force. In this manner, the substrate **180** can be coupled to the base **172** such that the substrate **180** substantially conforms to the shape of one or more portions of the base **172** (e.g., the first protrusion **174**). As described herein, this arrangement allows the substrate **180** to be wrapped, woven, and/or otherwise positioned relative to the base **172** in a flexible manner.

The flexibility of the substrate **180** is an extensive property, and thus is dependent upon the properties of the material from which the substrate **180** is constructed as well as certain physical characteristics of the substrate **180** (e.g., shape). For example, the flexibility of the substrate **180** can be increased by constructing the substrate **180** from a material having a low modulus of elasticity and/or a low flexural modulus. In some embodiments the substrate **180** can have a modulus of elasticity and/or a flexural modulus of less than approximately 750,000 p.s.i. In other embodiments the substrate **180** can have a modulus of elasticity and/or a flexural modulus of less than approximately 400,000 p.s.i.

The flexibility of the substrate **180** can also be increased or decreased by changing the shape, cross-sectional area and/or thickness of the substrate **180**. Although the substrate **180** is shown as being substantially planar and having a substantially constant thickness, in other embodiments, the substrate **180** can have a non-uniform thickness and/or can have an irregular cross-sectional shape (e.g., corrugations or the like) to result in the desired flexibility. Additionally, to increase the flexibility, the substrate **180** can be thin. In some embodiments, for example, the substrate **180** can have a thickness of approximately 50 to approximately 120 microns (approximately 0.002 to approximately 0.005 inches) or less.

In some embodiments, the substrate **180** can be a polymer, such as a polyester film, a polyimide film, or the like. Such polymers can also include, for example, Mylar®, Kapton® or the like. In other embodiments, the substrate **180** can be a reinforced polymer that includes, for example, a polymer reinforced with glass fibers, graphite fibers, or the like. Such materials can provide the electrical properties (e.g., resistivity and/or conductivity) and the mechanical properties (e.g., toughness, tear resistance, or the like) desired.

The substrate **180** has a first surface **181** and a second surface **182**. As shown in FIGS. **34-35**, the substrate **180** is coupled to the base **172** such that a first portion of the second surface **182** is in contact with the first protrusion **174**. A second portion of the second surface **182** is non-parallel to the first protrusion **174**. Said another way, when the substrate **180** is coupled to the base **172**, a portion of the substrate **180** is wrapped and/or woven about the first protrusion **174**. Similarly stated, when the substrate **180** is coupled to the base **172**, a portion of the substrate **180** is non-planar. The flexibility of the substrate **180** facilitates coupling of the substrate to the base **172** such that the substrate **180** is partially disposed about the first protrusion **174**.

The substrate **180** includes an electrical circuit **185**. The electrical circuit **185** is configured to electronically couple the electronic device to at least one of an electrode, a battery, or an antenna (not shown in FIGS. **34-35**). In this manner, for example, the electrode can receive an electrical signal or stimulation from the electronic device via the electrical circuit **185**. Also in this manner, the battery can provide power to the electronic device via the electrical circuit **185**, for example, to provide sufficient power to the electronic device for the electronic device to generate an electrical signal or stimulation. In another example, the electrical circuit **185** can include the antenna (e.g., an antenna similar to at least one of antennae **614**, **616**, **764**, **774**, **784**, **794**), which can be in wireless electrical communication with the electronic device. In some embodiments, at least one of the electrode, battery, or antenna is coupled to or otherwise disposed on the substrate **180**.

FIGS. **36-38** show a portion of a stimulation system **370** according to an embodiment. The stimulation system can be configured for use with a system to transmit an electrical signal from an electronic device (not shown) to a bodily tissue of a patient. The electronic device can be any suitable electronic device for producing an electrical signal, including any of the electronic devices shown and described herein.

The portion of the stimulation system **370** includes a substantially rigid base **372** and a flexible substrate **380**. The flexibility of the substrate **380** facilitates conformance of the substrate **380** to portions of the base **372** and/or to a curvature of a body of the patient. Because the base **372** is substantially rigid, the base is configured to provide structural support to the substrate **380** when the substrate **380** is coupled to the base. The base **372** also has sufficient structural integrity to couple the electronic device to the portion of the stimulation system **370** and/or support the electronic device relative to the stimulation system.

The base **372** includes a first protrusion **374** and a second protrusion **376**. The first protrusion **374** and the second protrusion **376** of the base **372** are each configured to maintain contact (e.g., electrical and/or physical contact) between the electronic device and at least the portion the stimulation system **370**. For example, at least a portion of the electronic device can be received between the first protrusion **374** and the second protrusion **376** of the base **372**. In some embodiments, for example, the first protrusion **374** and the second protrusion **376** are configured to be positioned adjacent a first end portion and a second end portion, respectively, of the electronic device when the electronic device is received between the first protrusion **374** and the second protrusion **376**. In some embodiments, the first protrusion **374** and the second protrusion **376** collectively define an interference fit and/or a "snap fit" with the electronic device when the electronic device is received between the first protrusion **374** and the second protrusion **376**. In this manner, the first protrusion **374** and/or the second protrusion **376** limit the movement of the electronic device relative to the base **372** when the electronic device is coupled to the base **372**. In some embodiments, for example, the first protrusion **374** and/or the second protrusion **376** are configured to matingly engage (e.g., via a tab, recess, detent or the like) a portion of the electronic device. In some embodiments, the second protrusion **376** is engaged with an end of the electronic device when the electronic device is coupled to the base **372** (e.g., as shown and described herein with respect to protrusion **911** of apparatus **901**).



The base **372** defines a set of slots including a first slot **371**, a second slot **373**, and a third slot **375**, each being different than the others. Similarly stated, the base **372** defines a series of elongated openings **371**, **373**, **375** that are distinct and/or non contiguous from each other. In other embodiments, however, the first slot **371**, the second slot **373** and/or the third slot **375** can be contiguous and/or can share at least a portion of a common boundary. The first slot **371**, the second slot **373** and the third slot **375** each receive a portion of the flexible substrate **380** when the flexible substrate **380** is coupled to the base **372**. Similarly stated, the flexible substrate **380** is woven within the first slot **371**, the second slot **373** and the third slot **375**. More particularly, at least a first portion of the substrate **380** is disposed within the first slot **371** defined by the base, and at least a second portion of the substrate is disposed within the second slot **373** defined by the base, as illustrated in FIGS. **36-37**.

The arrangement of the flexible substrate **380** within the first slot **371**, the second slot **373** and the third slot **375** results in at least a portion of the flexible substrate **380** being wrapped about the first protrusion **374** of the base **372**. In some embodiments, disposal of the substrate **380** within at least one of the slots **371**, **373**, **375** of the base **380** also serves to couple the substrate to the base **372**. Moreover, the arrangement of the flexible substrate **380** within the first slot **371**, the second slot **373** and the third slot **375** can be used to index and/or position the substrate **380** relative to the first protrusion **374** in a predetermined position. In this manner, as described in more detail below, a portion of the electrical circuit **385** included within the substrate **380** can be placed in electrical and/or physical contact with the electronic device.

The substrate **380** has a first surface **381** (e.g., an "upper surface") and a second surface **382** (e.g., a "lower surface"). The substrate **380** is coupled to the base **372** such that a first portion **383** of the second surface **382** of the substrate is in contact with the first protrusion **374** of the base. When the substrate **380** is coupled to the base **372**, a second portion **384** of the second surface **382** of the substrate **380** is non-parallel to the first portion **383** of the substrate, as illustrated in FIGS. **36-37**. For example, in some embodiments, the first portion **383** of the second surface **382** of the substrate **380** is substantially perpendicular to the second portion **384** of the second surface of the substrate **380** when the substrate **380** is coupled to the base **372**.

The substrate **380** includes an electrical circuit **385**. The electrical circuit **385** can include, for example, any suitable electrical components, via, conductors and/or the like interconnected to perform the functions described herein. More particularly, the electrical circuit **385** includes electrical pathways **387**, **386**, **389**. The electrical pathways can be, for example, conductive traces or metallic strips disposed on the flexible substrate **380**. At least a portion of the electrical circuit **385** is included on the first surface **381** of the substrate **380**, and is configured to be in electrical communication with the electronic device. For example, the portion of the electrical circuit **385** on the first surface **381** can be complementary to (e.g., on the opposite side of the substrate **380** from) the first portion **383** of the second surface **382** of the substrate **380**, such that the portion of the electrical circuit **385** is at least partially disposed about the first protrusion **374** of the base **372**. In this manner, for example, the portion of the electrical circuit **385** can be engaged with and/or disposed proximate to an end of the electronic device when the electronic device is coupled to the base **372**. When the portion of the electrical circuit **385** is engaged with and/or disposed proximate to an end of the electronic device, the electrical circuit **385** can electrically communicate with the electronic device in any manner described herein, including via wired and/or wireless electrical communication.

The electrical circuit **385** is configured to electronically couple the electronic device to at least one of an electrode, a battery, or an antenna. For example, as illustrated in FIG. **38**, the electrical circuit **385** can electronically couple the electronic device to a battery **394** via at least one electrical pathway **387**, **389** when the electronic device is coupled to the base **372**. More particularly, the battery **394** can be coupled to the first surface **381** of the flexible substrate **380** such that a portion of the electrical pathway **387** is electrically coupled to a first terminal of the battery **394** and a portion of the electrical pathway **389** is coupled to a second terminal of the battery **394**. In particular, the portion of the electrical pathway **389** is coupled to a second terminal of the battery **394** by a connector and/or tab similar to the conductive tabs **226**, **228** shown and described above. Corresponding terminals of the electronic device (not shown in FIGS. **36-38**) are also placed in electrical communication with the electrical pathways **387**, **389** when the electronic device is coupled to the base **372** to complete the electronic connection. In this manner, the battery **394** can provide power to the electronic device via the electrical circuit **385** when the electronic device is coupled to the base **372**.

The battery **394** can be any suitable battery, such as, for example, a Zinc-Air battery, a Silver-Oxide battery, a Lithium coin battery, a Lithium ion rechargeable battery and/or the like. In embodiments that include a rechargeable battery, the electronic device can be a recharging unit, and can be configured to supply power to the battery **394** via the electrical circuit **385** when the electronic device is coupled to the base **372**. Although stimulation system **370** is illustrated and described as including a battery **394**, in other embodiments, the stimulation system can include a different source of power, including any source of power shown and described herein.

As illustrated in FIG. **37**, the electrical circuit **385** can electronically couple the electronic device to an electrode **392** via an electrical pathway **386**. In use, an electrical signal or stimulus can be transmitted from the electronic device through the electrical pathway **386** to the electrode **392**. In addition to the electrode **392**, the electrical signal or stimulus can be transmitted via the electrical circuit **385** to at least one hydrogel electrode **397**, **399** coupled to the second surface **382** of the substrate **380**. More particularly, the electrical circuit **385** can electronically couple the electronic device to the hydrogel electrodes **397**, **399** (illustrated in FIG. **38**), such as via electrical pathway **388** or via electrical pathway **386** and electrode **392**, respectively.

At least a portion of the substrate **380** also includes a conductive region **398** and a plurality of non-conductive regions **396**. In particular, as illustrated in FIG. **37**, the second surface **382** of the substrate **380** can include at least one of the conductive region **398** and the plurality of non-conductive regions **396**. For example, at least one of the conductive region **398** and/or the plurality of non-conductive regions **396** can be disposed on the second surface **382** of the substrate **380**. As described herein, this arrangement facilitates both the mechanical and electrical coupling of the hydrogel electrode **397** and/or the hydrogel electrode **399** to the substrate **380**. In particular, as shown in FIGS. **37** and **38**, the conductive and non-conductive regions **398**, **396** are configured to contact the hydrogel electrode **397**. The conductive region **398** is in electrical communication with the electrical circuit **385**, e.g., via the electrical pathway **388**. As such, the conductive region **398** is configured to transmit an electrical signal or stimulus from the electrical circuit **385** to the hydrogel electrode **397**. In other embodiments, the substrate **380** can include more than one conductive region **398** and plurality of non-conductive regions. For example, in some embodiments, the substrate can include a second conductive region (not shown) and a second plurality of non-conductive regions (not shown) configured to place the hydrogel electrode **399** in electrical communication with the electrical circuit **385**, e.g., via the electrical pathway **386**.

In some embodiments, the plurality of non-conductive regions **396** is included within and/or adjacent the conductive region **398**. For example, the plurality of non-conductive regions **396** can be disposed on a surface of the conductive region **398**. Each non-conductive region of the plurality of non-conductive regions **396** is discrete from the other non-conductive regions of the plurality. At least one non-conductive region of the plurality of non-conductive regions **396** extends beyond (or away from) a surface of the conductive region **398**. Said another way, at least one non-conductive region of the plurality of non-conductive regions **396** is substantially non-planar with the conductive region **398**. Said yet another way, at least one non-conductive region of the plurality of non-conductive regions **396** forms a surface textured area on the conductive region **398** of the substrate **380**. In this manner, when the hydrogel electrode **397** is in contact with the substrate **380**, the plurality of non-conductive regions **396** and the conductive region **398** collectively reduce the likelihood that the hydrogel electrode **397** will peel or otherwise move away from the conductive region **398** of the substrate **380** (e.g., in the presence of shearing forces). As such, the plurality of non-conductive regions **396** is configured to facilitate coupling and/or the mechanical connection, between the hydrogel electrode **397** and the substrate **380**. Said another way, the plurality of non-conductive regions **396** is configured to facilitate retention of the hydrogel electrode **397** with respect to the conductive region **398** of the substrate **380**.

Further, because each discrete non-conductive region of the plurality **396** is surrounded on its perimeter by the conductive region **398**, an electrical current can be evenly distributed through the hydrogel electrode **397**. Even distribution of the electrical current from the conductive region **398** of the substrate **380** through the hydrogel electrode **397** can reduce and/or prevent electrical "hotspots" (i.e., areas of concentrated electrical stimulation that can cause skin irritation and/or uncomfortable sensations to a patient).

The plurality of non-conductive regions **396** can be formed in any suitable manner. For example, in some embodiments, at least one non-conductive region of the plurality of non-conductive regions **396** is a solder mask. Use of a solder mask to form the plurality of non-conductive regions **396** on the conductive region **398** permits the plurality of non-conductive regions to be formed in any suitable desired pattern on the conductive region **398**. Any known suitable method and/or material for producing the solder mask may be used. In another example, at least one non-conductive region is formed by a coating applied to the surface of the conductive region **398**.

Although the plurality of non-conductive regions **396** have been described herein as being disposed on the conductive region **398** of the substrate **380**, in other embodiments, the plurality of non-conductive regions can be included within and/or adjacent the conductive region in any suitable manner. For example, at least one non-conductive region of the plurality of non-conductive regions can be a cavity or other depressed portion formed in a surface of the conductive region of the substrate. The cavity can be configured to receive a portion of the hydrogel electrode, thereby facilitating retention of the hydrogel electrode with respect to the conductive region of the substrate. In some embodiments, the cavity is formed by etching one or more discrete portions of the conductive region. For example, in some embodiments, the conductive region includes a metal layer disposed on or otherwise coupled to the substrate and the plurality of non-conductive regions is formed by etching away discrete portions of the metal layer. In another example, at least one non-conductive region of the plurality of non-conductive regions can be an aperture or other opening defined by the conductive region of the substrate. Such an aperture or other opening can be formed, for example, by punching the aperture or other opening in the conductive region of the substrate with a mechanical punch. The aperture can be configured to receive a portion of the hydrogel electrode, thereby facilitating retention of the hydrogel electrode with respect to the conductive region of the substrate. Although various manners for forming the non-conductive regions have been described herein, the plurality of non-conductive regions can be formed in any suitable manner, including any combination of the foregoing manners.

Each non-conductive region of the plurality of non-conductive regions **396** can be of any suitable size and/or shape. For example, as illustrated in FIG. **37**, at least one non-conductive region of the plurality of non-conductive regions **396** can be in the shape of square (or a three-dimensional cube). The at least one non-conductive region can be, for example, a 1 mm×1 mm square. In other embodiments, at least one non-conductive region can be rectangular, triangular, oval, circular, or any other suitable shape. Additionally, the at least one non-conductive region can have dimensions of a size different than 1 mm×1 mm, such as a length, width, and/or cross-sectional diameter of greater than approximately 1 mm (e.g., approximately 2 mm to approximately 4 mm) or less than approximately 1 mm (e.g., approximately 0.3 mm to approximately 0.8 mm).

Although the portion of the substrate **380** including the conductive region **398** and the plurality of non-conductive regions **396** is illustrated and described as having a substantially circular shape, in other embodiments, the portion of the substrate can have any suitable shape. For example, in some embodiments, the portion of the substrate can be oval, rectangular, square, or another suitable shape.

Additionally, the portion of the substrate **380** including the conductive region **398** and plurality of non-conductive regions **396** can be of any suitable size. For example, the portion of the substrate **380** can have a diameter of approximately 30 mm. In another embodiments, the portion of the substrate can have a diameter of less than 30 mm (e.g., a diameter within the range of approximately 10 mm to approximately 30 mm). In still other embodiments, the portion of the substrate can have a diameter of greater than 30 mm (e.g., a diameter within the range of approximately 30 mm to approximately 60 mm).

The substrate **380** can be constructed of any suitable material. In some embodiments, for example, the substrate **380** is a flexible PCB. In another example, the substrate can be constructed of a different material, including silicon, polyamide, or another suitable polymer, or any combination of the foregoing.

Although stimulation system **370** is illustrated and described as having one portion of the substrate **380** including the conductive region **398** and the plurality of non-conductive regions **396** associated with the hydrogel electrode **397**, in other embodiments, an apparatus can include more than one conductive region and more than one plurality of non-conductive regions. For example, in other embodiments, the substrate can include a number of conductive region and a number of non-conductive regions corresponding to, or equivalent to, the number of hydrogel electrodes to be utilized with the apparatus (e.g., two, three, or more).

FIGS. **39-42** show portions of a stimulator assembly **495** according to an embodiment. In particular, the stimulator assembly **495** includes a battery **494**, an electrode **497**, a stimulus generator **490**, a substrate **480**, a base **472** and a housing **465**. The stimulator assembly **495** can be used to transmit an electrical current from the stimulus generator **490** to a bodily tissue of a patient. Components of the stimulator assembly **495** can be similar in many respects to components of apparatus shown and described herein (e.g., components of electrode-battery assembly **100**, apparatus **200**, stimulation system **370**, **570**).

The housing **465**, which is a substantially flexible housing, is configured to be disposed about at least a portion of a stimulator assembly **495** (e.g., the base **472**). Similarly stated, the housing **465** has a low resistance to deflection, deformation and/or displacement when exposed to an external force. In this manner, the housing **465** can be disposed about other portions of the stimulator assembly **495** such that the housing **465** substantially conforms to the shape of one or more of the other portions of the stimulator assembly (e.g., the protrusion **476**, the stimulus generator **490**, or the like). In some embodiments, the flexible housing **465** is configured to substantially prevent access of moisture to the portion of the stimulator assembly **495** about which the flexible housing **465** is disposed.

The flexible housing **465** includes a receiving portion **466**, which is configured to receive at least a portion of the stimulus generator **490**. The receiving portion **466** defines a first opening **468** (see FIG. **40**) and a second opening **469** (see FIG. **39**) different than the first opening. The first opening **468** is configured to receive a protrusion **491** of the stimulus generator **490**. The protrusion **491** of the stimulus generator **490** can include, for example, one or more electrical contacts **493** configured to place the stimulus generator **490** in electrical communication with other portions the stimulator assembly **495** (e.g., the battery **494**, the electrode **497**). The electrical contacts **493** can be any suitable mechanism for electrically coupling the stimulus generator **490** with other portions the stimulator assembly **495**. In some embodiments, the electrical contacts **493** are biased to help retain the stimulus generator **490** to the housing **465** and/or the stimulator assembly **495**. For example, the electrical contacts **493** can include a spring, which may also be configured to transmit an electrical current between the stimulus generator **490** and the stimulator assembly **495**, an elastomer, or other suitable biasing mechanism, or any combination of the foregoing.

The second opening **469** of the flexible housing **465** is configured to receive a protrusion **476** of the base **472**. The base **472** can be similar to the base **372** and/or the base **172** shown and described above. As described in more detail herein, the protrusion **476** of the base **472** is configured to couple the stimulus generator **490** to the housing **465** and other components of the stimulator assembly **495**. Although the first and second openings **468**, **469** of the housing **465** are illustrated as being defined by opposing ends of the receiving portion **466**, in other embodiments, the first opening and/or the second opening can be defined by a different portion of the receiving portion.

As shown in FIG. **42**, the housing **465** also defines a recess **464** configured to receive a fastening member **474** (shown in FIG. **39**) of the base **472**. A portion of the housing **465** has been removed in FIG. **42** for illustrative purposes only. The fastening member **474** can include end portions **475**, **475'**, each of which are configured to be received in respective openings **467**, **467'** defined by the housing **465**. The end portions **475**, **475'** are each configured to facilitate coupling of the housing **465** to the stimulator assembly **495** when the end portions **475**, **475'** are received in the openings **467**, **467'**. As such, when the flexible housing **465** is disposed about at least a portion of the stimulator assembly **495** and the fastening member **474** is received in the recess **464**, as illustrated in FIG. **40**, movement of the housing **465** relative to other portions of the stimulator assembly **495** is limited. In other words, the fastening member **474** is configured to couple or fasten the housing **465** to the other portions of the stimulator assembly **495** in a manner such that the lateral and/or vertical movement of the housing **465** with respect to the stimulator assembly **495** in the presence of substantially normal physical activities (e.g., walking, bathing, or the like) is substantially restricted.

When the fastening member **474** fastens the housing **465** to the remainder of the stimulator assembly **495**, the protrusion **476** of the base **472** is received within the opening **469** of the receiving portion **466**. The protrusion **476** is configured to limit movement of the stimulus generator **490** with respect to the housing **465** when the stimulus generator is received in the receiving portion **466** of the housing. In use, when the stimulator generator **490** is received in the receiving portion of the housing **465** and the protrusion **491** of the stimulus generator is received in the opening **469**, the protrusion **476** of the base **472** engages a portion of the stimulus generator **490**. For example, as illustrated in FIG. **39**, the protrusion **476** engages a recess **492** defined by the stimulus generator **490** when the stimulus generator **490** is received in the receiving portion **466** of the housing **465**. In some embodiments, the protrusion **476** is resiliently biased towards the portion of the stimulus generator **490**. In this manner, the protrusion **476** retains the stimulus generator **490** with respect to the housing **465** when the stimulus generator **490** is received in the receiving portion **466** of the housing, and thus limits movement of the stimulus generator **490** with respect to the housing **465**. Said another way, the resistance that occurs by engagement of the protrusion **476** with the portion of the stimulus generator **490** facilitates coupling of the stimulus generator **490** to the housing **465**. The protrusion **476** is configured to release the stimulus generator **490** when the protrusion **476** is pushed, depressed, or otherwise moved by the operator (e.g., a physician or the patient).

Although the recess **492** is illustrated as being on an end of the stimulus generator **490** that is opposite to an end of the stimulus generator including the protrusion **491**, in other embodiments, the recess (or other portion configured to engage protrusion **476**) can be defined by a different portion of the stimulus generator.

When the stimulus generator **490** is received in the receiving portion **466** and the protrusion **491** of the stimulus generator is received in the opening **468**, the stimulus generator **490** is electrically coupled to the battery **494**. In some embodiments, the stimulus generator **490** is electrically coupled to the battery **494** via an electrical circuit **485** disposed on the substrate **480** in a similar manner as described above with reference to the portion of the stimulation system **370**. The electrical circuit **485** includes at least one electrical pathway **487**. More particularly, when the protrusion **491** of the stimulus generator is received in the opening **468**, the electrical contacts **493** are placed in contact with the electrical circuit **485**. The battery **494** is also in electrical connection with the electrical circuit **485**, as described above, and thus the battery **494** is placed in electrical communication with the stimulus generator **490**. In other words, the electrical circuit **485** electrically couples the stimulus generator **490** to the battery **494**. The electrical circuit **485** can also electrically couple the stimulus generator **490** to the electrode **497**, as described above. The housing **465** is configured to substantially maintain the stimulus generator **490** in electrical communication with the electrical circuit **485** when the stimulus generator **490** is received in the receiving portion **466** and the housing **465** is disposed about at least a portion of the substrate **480** of the stimulator assembly **495**.

A portion of the housing **465** is configured to form a substantially fluid-tight seal proximate to the receiving portion **466** when the at least a portion of the stimulus generator **490** is received in the receiving portion **466**. In some embodiments, the housing **465** can form a seal to substantially prevent passage of a fluid from an area exterior to the housing and the stimulus generator **490** to an area interior to the housing **465** and/or an area between the housing **465** and the stimulus generator **490** (e.g. between a perimeter of the receiving portion **466** and the stimulus generator). In another example, the housing **465** can form a seal about the opening **468** when the protrusion **491** of the stimulus generator **490** is received in the opening to substantially prevent passage of a fluid therethrough. The fluid can be, for example, a liquid, a slurry, a gas, or the like. Thus, the housing **465** and/or the stimulator assembly **495** can be characterized as being water-resistant.

The housing **465** can be constructed from any suitable material to provide the desired flexibility, sealing properties or the like. In some embodiments, the housing **465** can be constructed from a polymer or rubber compound having a modulus of elasticity and/or a flexural modulus of less than approximately 750,000 p.s.i. In some embodiments, the housing **465** can be constructed of an elastomer. The elastomer can be injection molded, e.g., from a bio-compatible material. In some embodiments, the elastomer has a mechanical elasticity of about 40 Shore D. Thus, the housing is soft and flexible, which facilitates compliance with a curvature of the patient's body and which facilitates accurate positioning of rigid parts of the stimulator assembly **495** (e.g., the battery **494**, the stimulus generator **490**) on the patient's body. For example, in some embodiments, the housing **465** exhibits a degree of flexibility that permits the housing **465** to be placed substantially about a surface of a radial body part of the patient (e.g., an arm, a leg, or other limb). Although the housing **465** is described herein as being constructed of an elastomer, in other embodiments, the housing **465** can be constructed of any suitable material, including, for example, a silicon, polyamide, or another suitable polymer, or any combination of the foregoing.

The housing **465** can be disposed on or coupled to the body of the patient in any suitable known manner. For example, the housing **465** can be coupled to the body using a medical plaster, which may be beneficial for larger bodily areas, including an abdomen or a backside of a shoulder. In another example, the housing **465** can be coupled to the body of the patient using a band, which may be beneficial for parts of the patient's body having a substantially circular cross-section (e.g., the arm, leg, or other limb). Use of the band also permits easy attachment, detachment, and repositioning of the housing **465** on the body of the patient.

In some embodiments, as illustrated in FIG. **52**, a housing **190** can be configured to prevent migration and/or displacement of an electrode (e.g., a hydrogel electrode, not shown in

FIG. **52**,) with respect to the housing in the presence of a shearing force and/or a mechanical stress. The housing **190** includes a flange **194** that extends from a body portion **196** of the housing to form a channel **198**. In some embodiments, as illustrated in the cross-sectional view of the housing **190** shown in FIG. **52**, the flange **194** forms a substantially continuous rim about a lower portion of the body portion **196** of the housing **190**. In other embodiments, however, the housing can include a plurality of discrete flanges, which collectively form a discontinuous and/or non-contiguous rim about the lower portion of the body portion of the housing. For example, the housing can include two or more flanges disposed on the body portion at spaced (e.g., opposing) locations.

The channel **198** is configured to receive a portion of the periphery (or edge) of the electrode. In the embodiment illustrated in FIG. **52**, the channel **198** is substantially U-shaped, however, in other embodiments, the channel can be any suitable shape for receiving a portion of the periphery of the electrode. When the peripheral portion of the electrode is received in the channel **198** of the flange **194**, lateral movement of the electrode relative to the housing is restricted. In this manner, the housing **190** is configured to couple the electrode to the housing, and thus to a stimulator assembly (not shown in FIG. **52**) to which the housing is attached.

Although the flange **194** and channel **198** have been illustrated and described herein as being integrally formed with the housing **190**, in other embodiments, the electrode rim, or a portion thereof, can be manufactured as a separate and distinct portion that is couplable to the housing.

Further, although the housing **190** has been illustrated and described herein as including the electrode rim, in other embodiments, the electrode rim can be included in or coupled to a different portion of the stimulator assembly. For example, as illustrated in FIG. **53**, a stimulator assembly **289** includes a rim **290**, which is removably couplable to a base **246** of the stimulator assembly, as described herein. The rim **290** includes a body portion **296** and a flange **294**. The flange **294** of the rim **290** is extended from the body portion **296** and forms a channel **298** between the flange and the body portion. The flange **294** is disposed about a portion of a periphery of at least one electrode **299** (e.g., a hydrogel electrode) such that a portion of the electrode's periphery **297** is received in the channel **298**. In some embodiments, the electrode **299** is fixedly received in the channel **298** of the rim **290**. In other embodiments, the electrode **299** is removably received in the channel **298** of the rim **290**. The electrode **299** can be disposed within the channel **298** of the rim **290** during the manufacturing process, e.g., to permit distribution of the electrode and rim in a single package. As illustrated in FIG. **53**, a protrusion **247** of the base **246** includes a recess **248** that is configured to receive a portion of the body portion **296** of the rim **290**, and thus is configured to couple the rim **290** and electrode **299** to the base **246**. As such, the rim **290** facilitates attachment, removal and/or replacement of the electrode **299** with respect to the stimulator assembly **289**.

Although the rim **290** is shown and described above as being coupled to the base using recess **248** of the protrusion **247** of the base, in other embodiments, the rim **290** can be differently coupled to the base. For example, in some embodiments, the rim **290** can be coupled to the base with an elastic configured to be disposed about a portion of the base, a clip, a hook and loop fastener, or an adhesive, or any combination of the foregoing.

Further, in other embodiments, the electrode rim can be configured to be coupled to a different portion of a stimulator assembly, including, but not limited to, a substrate of the stimulator assembly. In still other embodiments, an electrode rim can integrally formed with a base, substrate, or other suitable portion of a stimulator assembly.

FIGS. **43-47** illustrate a portion of a stimulation system **570** according to an embodiment. The portion of the stimulation system **570** is configured to deliver an electrical current from an electronic device (not shown) to a bodily tissue of a patient. The portion of the stimulation system **570** includes a substrate **580**, a power source **594**, a casing **592**, electrodes **597**, **599**, an electrical circuit **585**, a coupling member **572**, and a housing **565**, each of which are coupled to or otherwise disposed on the substrate **580**.

The substrate **580** is flexible such that the substrate can substantially conform to the contours of the portion of the patient's body on which the portion of the stimulation system **570** is disposed. For example, the substrate **580** can be configured to be flexible such that the substrate conforms to the curvature of a patient's arm, leg, or back. In this manner, the substrate **580** is configured to facilitate positioning and placement of the stimulation system on the patient's body. In some embodiments, the substrate **580** can be similar to and/or constructed from similar materials as any of the substrates shown and described herein.

The substrate **580** has a first configuration and a second configuration different than the first configuration. In its first configuration, the substrate **580** has a first area (see, e.g., FIG. **45**). Similarly stated, when the substrate **580** is in its first (or unfolded) configuration, the substrate **580** occupies a first surface area and/or defines a first "footprint."When the substrate **580** is in its first configuration, each of the electrodes **597**, **599** and the electrical circuit **585** face a first direction and are disposed on a first side **581** of the substrate. For example, when the substrate **580** is in its first configuration and the substrate is positioned horizontally, the electrodes **597**, **599** and the electrical circuit **585** can be characterized as facing "up."

In its second configuration, the substrate **580** has a second area less than the first area (see, e.g., FIGS. **46-47**). Similarly stated, when the substrate **580** is in its second (or folded) configuration, the substrate **580** occupies a second surface area and/or defines a second "footprint" that is smaller than the first "footprint." When the substrate **580** is in its second configuration, the electrodes **597**, **599** and at least a portion of the electrical circuit **585** each face a second direction different than the first direction, as illustrated in FIGS. **45-46**. For example, when the substrate **580** is in its second configuration and the substrate is positioned horizontally, the electrodes **597**, **599** and the portion of the electrical circuit **585** can be characterized as facing "down," or towards the bodily tissue, while the remaining portion of the electrical circuit remains facing "up," or away from the bodily tissue. The substrate **580** can be moved from its first configuration to its second configuration, for example, by folding under at least one of tab portion **596** or tab portion **598**, as shown in FIGS. **46-47**, respectively. Because the substrate **580** is flexible, the substrate is not damaged (e.g., cracked, broken, or creased) when the at least one of the tab portions **596**, **598** is folded under. Because the electrodes **597**, **599** and the electrical circuit **585** are formed on a first side **581** of the substrate **580**, manufacturing of the substrate **580** is more easily accomplished. For example, in some embodiments, the electrodes **597**, **599** and/or electrical circuit **585** can be formed by an electrically conductive ink printed onto the first side of the substrate **580**.

As illustrated in FIG. **44**, the power source **594** is coupled to the first side **581** of the substrate **580**. The power source **594** can be any suitable source of power for providing power to the electronic device, including any source of power shown and described herein. For example, the power source **594** can be a lithium battery, a rechargeable battery or the like. In some embodiments, the power source **594** provides enough power for approximately one week of standard use by a patient. In other embodiments, the power source **594** provides power for a longer period of time.

The casing **592** includes a rim **593** and defines a cavity (not shown, but indicated by arrow **595**). The power source **594** is received in the cavity **595** of the casing **592**. The rim **593** of the casing **592** is coupled to the substrate **580** to form a seal configured to substantially prevent the passage of moisture between the rim **593** of the casing **592** and the substrate **580**. In this manner, the casing **592** substantially prevents entry of moisture into the cavity **593**, and thus onto the power source **594** and/or the portion of the electrical circuit **585** coupled to the power source. As such, the casing **592** can limit a short-circuit of the power source **594** caused by exposure to moisture during the patient's daily activities, including bathing, perspiring, or swimming.

The electrical circuit **585** is configured to electrically couple each of the power source **594** and the electrodes **597**, **599** to the electronic device. Each electrode **597**, **599** is configured to contact a bodily tissue (either directly or via a secondary electrode), and to convey an electrical current between the electronic device and the bodily tissue. In some embodiments, at least one electrode **597**, **599** can be associated with a hydrogel electrode. For example, a hydrogel electrode can be bonded to the substrate surrounding the perimeter of the at least one electrode **597**, **599** such that the hydrogel electrode is disposed over and in electrical communication with the at least one electrode **597**, **599**.

The coupling member **572** is coupled to the flexible substrate **580**. More particularly, the coupling member **572** defines a first slot **571** and a second slot **573** different than the first slot. As illustrated in FIG. **43**, at least a first portion of the substrate **580** is disposed within the first slot **571**, and at least a second portion of the substrate is disposed within the second slot **573**. In some embodiments, the coupling member **572** is substantially rigid, and therefore provides support to the flexible substrate **580**. In some embodiments, the coupling member **572** can be similar in many respects to the base **372** described above with respect to the stimulation system **370**.

The coupling member **572** also includes a connective member **574** and a protrusion **576**. The substrate **580** is coupled to the connective member **574** such that a first portion **581'** of the first side **581** of the substrate **580** is non-parallel to a second portion **581"** of the first side of the substrate, as illustrated in FIG. **43**. A portion of the electrical circuit **585** is disposed on the second portion **581"** of the first side **581** of the substrate **580**. Thus, the portion of the electrical circuit **585** is disposed proximate to a portion of the electronic device when the electronic device is coupled to the stimulation system **570**, as described in more detail herein.

The coupling member **572** is configured to receive at least a portion of the electronic device in an area between the connective member **574** and the protrusion **576**. The protrusion **576** of the coupling member **572** is configured to releasably couple the electronic device to the substrate **580**. In some embodiments, the protrusion **576** is configured to releasably engage a recess of the electronic device (e.g., as shown and described above with respect to protrusion **476** and stimulus generator **490**).

The housing **565** can be similar in many respects to housing **465** described herein. The housing **565** is disposable over at least a portion of the substrate **580**. The housing includes a receiving portion **566** and defines an opening **569**. The receiving portion **566** is configured to receive at least a portion of the electronic device. In some embodiments, the receiving portion **566** is defined by a surface **567** of the housing. The opening **569** of the housing **565** is configured to receive the protrusion **576** of the coupling member **572**. In this manner, the protrusion **576** is configured to releasably engage the recess of the electronic device when the electronic device is disposed in the receiving portion **566** of the housing **565**, and the protrusion **576** is received in the opening **569** defined by the housing.

In use, when the electronic device is received in the receiving portion **566** of the housing **565**, the electronic device is placed in electrical communication with the electrical circuit **585**. As such, the power source **594** can provide power to the electronic device such that the electronic device can generate an electrical current. The electrical current generated by the electronic device is transmitted from the electronic device to the electrical circuit **585**. The electrical current is then transmitted from the electrical circuit **585** to the electrodes **597**, **599**. The electrodes **597**, **599** convey the electrical current to the bodily tissue, thereby providing stimulation to the bodily tissue. In some embodiments, the electrodes **597**, **599** are also configured to receive the electrical current from the bodily tissue, and to transmit the electrical current to the electronic device via the electrical pathway. In some embodiments, the stimulation system **570**, or a portion thereof, is disposable. For example, the stimulation system **570** can be disposed of once the power source **594** is depleted and/or once the hydrogel electrode is no longer suitable for use (e.g., after approximately two weeks of continuous use). The usable life of the hydrogel electrode can be extended, however, if the electrode is stored properly when not in use (e.g., by applying a liner foil to the electrode to protect the hydrogel from humidity changes).

In some embodiments, however, the power source is removable and/or replaceable, for example when the power source is low or depleted after use. As illustrated in FIGS. **54-55**, a stimulator assembly **860** according to an embodiment is configured to transmit electrical stimulation to a body of a patient and includes a flexible housing **880**, a stimulus generator **862**, and a removable power source **870**.

The stimulus generator **862** can be similar in many respects to the stimulus generator **490**, described above. The housing **880** includes a first receiving portion **881**, which is configured to receive a portion of the stimulus generator **862**. The stimulus generator **862** can be removably coupled to the housing **880** in any suitable manner described herein. For example, the stimulus generator **862** can be coupled to the housing **880** when the portion of the stimulus generator **862** is received in the first receiving portion **881** and a protrusion **865** of a base (not shown) of the stimulator assembly **860** engages a recess **863** of the stimulus generator.

The housing **880** defines a second receiving portion **882**, which is configured to receive a portion of the power source **870**, different than the first receiving portion **881**. The receiving portions **881**, **882** can be similar in many respects to receiving portion **466** described above. For example, the second receiving portion **882** defines a first opening (not shown in FIGS. **54-55**) that is configured to receive a protrusion **874** of the power source **870**. The protrusion **874** of the power source **870** can include, for example, one or more electrical contacts configured to place the power source **870** in electrical communication with other portions the stimulator assembly **860** (e.g., the stimulus generator **862**, an electrical pathway, an electrode). The electrical contacts can be any suitable mechanism for electrically coupling the power source **870** with other portions the stimulator assembly **860**. In some embodiments, the electrical contacts are biased to help retain the power source to the housing **880** and/or the stimulator assembly **860**. For example, the electrical contacts can include a spring, an elastomer, or other suitable biasing mechanism.

The second receiving portion **882** also defines a second opening (not shown in FIGS. **54-55**), which is configured to receive a protrusion **866** of a base **864** (shown in dashed lines in FIG. **54**) of the stimulator assembly **860**. The base **864** can be similar in many respects to the base **472**, base **372** and/or the base **172** shown and described above.

The protrusion **866** of the base **864** is configured to couple the power source **870** to the housing **880** and other components of the stimulator assembly **860**. Specifically, the protrusion **866** is configured to limit movement of the power source **870** with respect to the housing **880** when the power source is received in the receiving portion **882** of the housing. In use, when the power source **870** is received in the receiving portion of the housing **880** and the protrusion **874** of the power source is received in the first opening of the housing, the protrusion **866** of the base **864** engages a portion of the power source. For example, as illustrated in FIG. **54-55**, the protrusion **866** engages a recess **876** defined by the power source **870** when the power source is received in the receiving portion **882** of the housing **880**. In some embodiments, the protrusion **866** is resiliently biased towards the portion of the power source **870**. In this manner, the protrusion **866** retains the power source **870** with respect to the housing **880** when the power source is received in the receiving portion **882** of the housing, and thus limits movement of the power source with respect to the housing **880**. Said another way, the resistance that occurs by engagement of the protrusion **866** with the portion of the power source **870** facilitates coupling of the power source to the housing **880**. The protrusion **866** is configured to release the power source **870** when the protrusion **866** is pushed, depressed, or otherwise moved by the operator (e.g., a physician, patient, or other user). Although the recess **876** is illustrated as being on an end of the power source **870** that is opposite to an end of the power source including the protrusion **874**, in other embodiments, the recess (or other portion configured to engage protrusion **866**) can be defined by a different portion of the power source.

Because the power source **870** is removable the operator can remove the power source from the stimulator assembly **860**, for example, when the power source is depleted or otherwise insufficiently charged. After removal of the power source **870**, a replacement power source of similar construct can be coupled to the stimulator assembly **860**. In some embodiments, the power source **870** is also rechargeable. As such, at least a portion of the power source **870** is configured to be coupled to an external charging station, e.g., after removal from the stimulator assembly **860**. While the power source **870** is being recharged, a second power source of similar construct can be used with the stimulator assembly **860**, thus allowing for substantially uninterrupted treatment for the patient. Once the power source **870** is recharged to a sufficient power level and/or the secondary power source is depleted, the power source **870** can be re-coupled to the stimulator assembly **860**.

Because each of the power source **870** and the stimulus generator **862** are removably couplable to the housing **880**, in some embodiments, the housing and/or other portions of the stimulator assembly **860** (e.g., an electrical pathway, an electrode) can be disposable. In this manner, the operator can selectively replace, for example, a used electrode coupled to the housing with another housing including an unused electrode. Also in this manner, manufacturing costs for the stimulator assembly **860** can be reduced because the power source **870** and/or stimulus generator **860** are reusable instead of being disposed with the housing **880**. Furthermore, the power source **870** and stimulus generator **862** can be used with another stimulator assembly having a footprint (i.e., the configuration of a portion of the stimulator assembly facing a patient's body) that is different than a footprint of the stimulator assembly **860** and that includes a receiving portion configured to receive at least one of the power source and stimulus generator. As such, at least one of the power source **870** and stimulus generator **862** can be configured for use with a housing adapted to a specific anatomical location (e.g., a shoulder, a knee, a lower back).

When the power source **870** is received in the receiving portion **882** and the protrusion **874** of the power source is received in the first opening of the housing, the power source is electrically coupled to the stimulus generator **862**. In some embodiments, the power source **870** is electrically coupled to the stimulus generator **862** via an electrical pathway (not shown in FIGS. **54-55**) disposed on a substrate (not shown in FIGS. **54-55**) of the stimulator assembly **860** in a similar manner as shown and described above with reference to substrate **380**. More particularly, when the protrusion **874** of the power source **870** is received in the opening of the housing **880**, the electrical contacts are placed in contact with the electrical pathway. The stimulus generator **862** is also in electrical connection with the electrical pathway, and thus is placed in electrical communication with the power source **870**. In other words, the electrical pathway electrically couples the stimulus generator **862** to the power source **870**. The housing **880** is configured to substantially maintain the power source **870** in electrical communication with the electrical pathway when the power source is received in the receiving portion **882** and the housing **880** is disposed about at least a portion of the substrate of the stimulator assembly **860**. The housing **880** can be constructed of any suitable material, including those materials described above with respect to housing **465**.

In some embodiments, the power source **870** includes a battery (not shown) and a casing **871**. The battery is received in a cavity (not shown) of the casing **871**. The casing **871** can be configured to substantially prevent the passage of moisture between an area external to the casing **871** and the cavity of the casing. In this manner, the casing **871** substantially prevents entry of moisture into the cavity, and thus onto the battery. As such, the casing **871** can limit a short-circuit of the battery caused by exposure to moisture during the patient's daily activities, including bathing, perspiring, or swimming. The casing **871** also can help prevent inadvertent disconnection of the battery caused by friction that occurs during the patient's daily activities, including walking or dressing.

In some embodiments, the casing **871** includes a panel (not shown) movable between an open position, in which the cavity is accessible from an area external to the casing, and a closed position, in which the cavity is sealed and/or otherwise inaccessible from an area external to the casing. When the panel of the casing **871** is in its open position, the battery can be removed from and/or inserted into the cavity, e.g., to remove and/or replace a depleted battery. In some embodiments in which the power source **870** is rechargeable, at least one of the casing **871** or the battery is configured to be coupled to an external charging station. The battery can be any suitable source of power described herein, including as described above with respect to battery **394**.

Although the power source **870** has been illustrated and described herein as being coupled to the stimulator assembly **860** with protrusion **866** of the base **882**, in other embodiments, the power source can be coupled to the stimulator assembly in a different manner, for example, as shown and described above with respect to apparatus **951**.

Although stimulator system **570** and stimulator assembly **860** have been described herein as being wholly disposable or having a disposable housing, respectively, in other embodiments, a stimulator system can include a different disposable portion and/or reusable portion. Schematically illustrated in FIG. **56**, a stimulator system **1000** according to an embodiment is configured to generate and transmit electrical stimulation through a bodily tissue of a patient. The stimulator system **1000** includes a stimulator assembly **1010** removably coupled to an electrode assembly **1040**. Components of the stimulator system **1000** can be similar in many respects to components of apparatus shown and described herein (e.g., components of apparatus **100**, **200**, stimulation system **370**, **570**, stimulator assembly **495**, **860**). Referring to FIG. **56**, the stimulator assembly **1010** includes a housing **1012**, an electrical pathway **1014**, a first connector assembly **1016**, a stimulus generator **1020**, and a power source **1030**.

The stimulus generator **1020** is configured to generate the electrical stimulation. The stimulus generator **1020** can be similar in many respects to any stimulus generator described herein (e.g., external stimulator $S_1$-$S_{11}$, stimulus generator **490**, **862**), except that the stimulus generator need not be configured to be external and/or removable. In other words, the stimulus generator **1020** can include internal components configured to generate the electrical stimulation similar to the internal components of any stimulus generator described herein, but need not have an external casing, generally, or an external casing that is removably couplable to the housing, specifically. For example, in some embodiments, the stimulus generator **1020** includes various electronic components that collectively are configured to generate the electrical stimulation and that are collectively disposed within the housing **1012** (e.g., on a substrate, not shown). The stimulus generator **1020** is electrically coupled to the power source **1030** via the electrical pathway **1014**. The stimulus generator **1020** is also electrically couplable to the electrode assembly **1040** via the electrical pathway **1014** and via the first connector assembly **1016**.

The power source **1030** is configured to provide power to the stimulus generator **1020** via the electrical pathway **1014**. The power source **1030** is configured to be rechargeable. More specifically, in some embodiments, the power source **1030** is configured to be recharged when the power source is enclosed within the housing **1012**. The power source **1030** is configured to be in electrical communication with an external charger (not shown in FIG. **56**) by the electrical pathway **1014** and the first connector assembly **1016**. The power source can be any suitable energy supplying source that may or may not be rechargeable. For example, in some embodiments, is a conventional disposable battery. In some embodiments, the power source is a rechargeable battery. Specifically, the power source can be a Li-polymer battery (e.g., a 500 mAh Li-polymer battery). In some embodiments, the power source is a rechargeable version of any suitable source of power described herein.

The power source **1030** is configured to provide power to the stimulus generator **1020** over a long duration of time, with recharging. For example, in some embodiments, the power source **1030** is configured to provide power to the stimulus generator **1020** over a period of at least six months of standard use by a patient, with recharging. In some embodiments, the power source **1030** is configured to provide power over a period of at least one year, with recharging. In some embodiments, the power source **1030** is configured to provide power over a period of about two years, with recharging. In other embodiments, the power source **1030** is configured to provide power to the stimulus generator **1020** for a period of less than six months of standard use by the patient. For example, in some embodiments, the power source **1030** is configured to provide power to the stimulus generator **1020** over a period of about one month, with recharging. In another example, in some embodiments, the power source **1030** is configured to provide power over a period of about one week, with recharging.

The power source **1030** is configured to provide power to the stimulus generator **1020** for a shorter duration on a single charge (i.e., before being depleted to a level insufficient to power the stimulus generator **1020**). For example, in some embodiments, the power source **1030** is configured to provide power for up to twelve hours on a single charge. In other embodiments, the power source **1030** is configured to provide power to the stimulus generator **1020** for at least twelve hours on a single charge. For example, in some embodiments, the power source **1030** is configured to provide power to the stimulus generator **1020** for at least twenty-four hours on a single charge. In another example, in some embodiments, the power source **1030** is configured to provide power for forty-eight or more hours on a single charge. In still another example, in some embodiments, the power source **1030** is configured to provide power for more three, four, or more days on a single charge. Although the stimulator assembly **1110** has been illustrated and described herein as including a permanent rechargeable power source **1130**, in other embodiments, a stimulator assembly can include a replaceable power source (e.g., as described above with respect to power source **870**).

The first connector assembly **1016** is configured to electrically couple the stimulator assembly **1010** to the electrode assembly **1040**. As illustrated in FIG. **56**, the first connector assembly **1016** is electrically coupled to the stimulus generator **1020** and the power source **1030**. In some embodiments, the first connector assembly **1016** is configured to provide both a mechanical and an electrical connection between the stimulator assembly **1010** and the electrode assembly **1040**. Said another way, when the stimulator assembly **1010** is mechanically coupled to the electrode assembly **1040** via the first connector assembly **1016**, the stimulator assembly **1010** is also placed in electrical communication with the electrode assembly **1040**. The first connector assembly **1016** can include any suitable mechanism for electrically and/or mechanically connecting the stimulator assembly **1010** to the electrode assembly **1040**, including but not limited to, a snap-fit connector. In some embodiments, the first connector assembly **1016** includes a metal electrode. In some embodiments, the first connector assembly **1016** includes a conductive ink, a wire, or the like. In some embodiments, the first connector assembly **1016** is formed in a unique shape to ensure that only electrodes with a corresponding-shape connector (e.g., second connector assembly **1044**, described below) can be coupled to the housing **1012**. Such a configuration can also ensure that the housing **1012** is coupled to the electrode in a pre-determined orientation.

The first connector assembly **1016** is configured to electrically couple the power source **1030** to an external charger (not shown in FIG. **56**). In some embodiments, the first connector assembly **1016** is configured to mechanically couple the power source **1030** to the external charger. In some embodiments, the first connector assembly **1016** is configured to both electrically and mechanically couple the power source **1030** to the external charger. The first connector assembly **1016** can include any suitable mechanism for electrically coupling the power source **1030** to the external charger, including, but not limited to, a mechanism described above with respect to connections between the stimulator assembly **1010** and the electrode assembly **1040**. In some embodiments, the first connector assembly **1016** includes at least a first connector (not shown) configured to electrically and/or mechanically couple the stimulator assembly **1010** to the electrode assembly **1040** and a second connector (not shown) different than the first connector and configured to electrically and/or mechanically couple the stimulator assembly to the external charger. In this manner, in some embodiments, the stimulator assembly **1010** is configured to be simultaneously connected to both the electrode assembly **1040** and the external charger.

In some embodiments, the stimulator assembly **1010** is configured to prevent generation and/or transmission of the electrical stimulation to the electrode assembly **1040** when the stimulation assembly is connected to the external charger. In some embodiments, for example, the first connector assembly **1016** is configured to only permit an electrical and/or mechanical connection between the power source **1030** and the external charger when the stimulator assembly **1010** is not electrically connected to the electrode assembly **1040**. For example, a connector (not shown) of the first connector assembly **1016** can be configured for connection with each of the electrode assembly **1040** and the external charger such that when the connector is connected to one of the electrode assembly or the external charger it is prevented from being simultaneously connected to the other of the electrode assembly or the external charger. In other words, the connector is shared between the electrode assembly **1040** and the external charger. As such, when the connector of the first connection assembly **1016** is connected to the external charger, it is prevented from also being connected to the electrode assembly **1040**. In other embodiments, the external charger is configured to physically interfere with a connection between the stimulator assembly **1010** and the electrode assembly **1040** when the external charger is connected to the stimulation assembly. In still other embodiments, the stimulator assembly **1010** can include additional hardware, software, or a combination thereof, configured to prevent simultaneous charging of the power source **1030** and transmission of the electrical stimulation to the electrode assembly **1040**.

The first connector assembly **1016** is disposed proximate to a bottom portion **1013** of the housing **1012**. In some embodiments, for example, the connector is substantially enclosed within a cavity **1015** of the housing **1012**. In some embodiments, the first connector assembly **1016** is disposed on an outer surface of the bottom portion **1013** of the housing **1012**, such that the first connector assembly is exterior to the cavity **1015** of the housing. In still other embodiments, a portion of the first connector assembly **1016** is enclosed within the cavity **1015** of the housing **1012** and another portion of the first connector assembly is exterior to the housing **1012**.

The electrical pathway **1014** is configured to electrically couple the first connector assembly **1016** to the at least one of the stimulus generator **1020** and the power source **1030**. In some embodiments, for example, the electrical pathway **1014** includes a wire configured to electrically connect the stimulus generator **1020** and the power source **1030**. In some embodiments, a portion of the electrical pathway **1014** is a pathway of conductive ink printed onto a substrate (not shown in FIG. **56**). The substrate can be, for example, any suitable substrate described herein (e.g., substrate **102**, PCB **202**, flexible substrate **380**, **580**). In another example, the substrate can be substantially rigid (e.g., have little to no compliance to a bodily curvature). In some embodiments, at least one of the electrical pathway **1014**, the first connector assembly **1016**, the stimulus generator **1020**, and the power source **1030**, or any combination thereof, is coupled to the substrate.

The housing **1012** is configured to at least partially enclose components of the stimulator assembly **1010**, such as, but not limited to, the stimulus generator **1020**, the power source **1030**, the electrical pathway **1014**, the first connector assembly **1016**, the substrate, or the like. In this manner, the housing **1012** is configured to protect the enclosed components from external contaminants, including, for example, exposure to dirt, moisture, fluids, and the like. In some embodiments, the housing **1012** defines an opening (not shown in FIG. **56**) configured to provide access to a portion of the first connector assembly **1016**. In some embodiments, such as when at least a portion of the first connector assembly **1016** is external to the housing **1012** cavity **1015**, the housing is disposed about the portion of the first connector assembly in such a manner as to provide a seal between the cavity and an area exterior to the cavity.

The housing **1012** is configured to be durable (e.g., by being constructed of durable materials). For example, the housing **1012** is configured withstand being bumped, exposed to moisture (e.g., humidity, sweat), and the like that occur during normal daily activities (e.g., walking, shopping). It is desirable that the housing **1012**, and the stimulator assembly **1010** generally, be configured for use in normal daily activities by a patient for a period of about two years. The housing **1012** can be constructed of any suitable material, including, but not limited to, any suitable material, or combination of materials, described herein (e.g., with respect to housing **465**).

In some embodiments, the stimulator assembly **1010** is configured to alert the user when the power source **1030** has been depleted to a threshold level. For example, in some embodiments, the stimulator assembly **1010** is configured to provide an audible alert (e.g., a beep, a recorded verbal warning), a tactile alert (e.g., a vibration), a visual alert (e.g., a light or other visual indicia), or a combination thereof, when the power source **1030** has been depleted to the threshold level. In some embodiments, the stimulator assembly **1010** is programmable, for example, so that the threshold level can be set by an operator (e.g., a physician, the patient, etc.).

The electrode assembly **1040** of the stimulator system **1000** is removably couplable to the stimulator assembly **1010**, as shown in FIGS. **56-57**. In some embodiments, the electrode assembly **1040** is configured to be coupled to the housing **1012** proximate to the bottom portion **1013** of the housing. The electrode assembly **1040** includes at least one electrode **1042** and a second connector assembly **1044**. In some embodiments, the second connector assembly **1044** of the electrode assembly **1040** is configured to be mechanically and/or electrically coupled to the first connector assembly **1016** of the stimulator assembly **1010**. In some embodiments, the second connector assembly **1044** is configured to provide both a mechanical and an electrical connection between the electrode assembly **1040** and the stimulator assembly **1010**. The second connector assembly **1044** can include any suitable mechanism for electrically and/or mechanically connecting the stimulator assembly **1010** to the electrode assembly **1040**. For example, the first connector assembly **1016** and the second connector assembly **1044** can include complementary (or mating) connectors (e.g., snap-fit connectors). In some embodiments, the second connector assembly **1044** includes a metal electrode. In some embodiments, the second connector assembly **1044** includes a conductive ink, a wire, or the like.

The electrode assembly **1040** is configured to receive the electrical stimulation from the stimulator assembly **1010** via the coupled connector assemblies **1016**, **1044**. The second connector assembly **1044** is configured to transmit the electrical stimulation to the electrode **1042**. The electrode **1042** is configured to facilitate transmission of the electrical stimulation through the bodily tissue. The electrode **1042** is configured to contact bodily tissue. For example, in some embodiments, the electrode assembly **1040** includes a hydrogel electrode configured to adhere to the patient's skin. The electrode assembly **1040** can remain in contact with (or adhered to) the bodily tissue when the stimulator assembly **1010** is decoupled from the electrode assembly **1040**.

The electrode assembly **1040** is disposable. For example, the electrode assembly **1040** can be disposed of once the electrode is no longer suitable for use (e.g., after approximately two weeks of continuous use). In use, the electrode assembly **1040** is decoupled from the stimulator assembly **1010** before being discarded. In this manner, the stimulator assembly **1010** can continue to be used with a replacement electrode assembly.

The electrode assembly **1040** can be of any desired shape, size, or footprint. For example, in some embodiments, the electrode assembly is configured to be positioned at a specific anatomical location, such as a lower back (FIG. **58**A), a shoulder (FIG. **58**B), an elbow (FIG. **58**C), or a knee (FIG. **58**D). In this manner, the electrode assembly **1040** is configured to comply with bodily curvature, which may facilitate adhesion of the electrode **1042** to the bodily tissue. As such, the electrode assembly **1040** may help eliminate the need for sleeves to maintain the assembly adjacent the desired bodily tissue. In some embodiments, the footprint of the electrode assembly **1040** is determined by a shape, size, or footprint of the electrode **1042**.

Although the electrode assembly **1040** has been illustrated and described herein as being configured to adhere to the bodily tissue, in some embodiments, a stimulation system includes an electrode assembly configured to be coupled to the bodily tissue in another manner. In some embodiments, a stimulation system includes an electrode assembly configured to be coupled to the bodily tissue by a garment. The garment is configured to maintain the electrode assembly at a desired position with respect to the bodily tissue. In some embodiments, the garment is configured to be securely wrapped about a portion of the stimulation system (e.g., the electrode assembly, a stimulation assembly, or both the electrode and stimulation assemblies). For example, in use, the electrode assembly can be disposed at the desired position with respect to the bodily tissue and then garment can be securely wrapped about the electrode assembly (and, optionally, about a portion of the patient's body) to couple the electrode assembly to the bodily tissue. The garment can define an opening, for example, to permit access to a connector assembly of the electrode assembly. In this manner, a stimulator assembly of the stimulation system can be coupled to the electrode assembly when the electrode assembly is coupled to the bodily tissue using the garment. In another example, the stimulator assembly and electrode assembly can be coupled together and disposed at the desired position with respect to the bodily tissue, and the garment can be disposed about the coupled stimulator and electrode assemblies so that the electrode assembly is coupled to the bodily tissue.

In some embodiments, the garment includes at least a portion of the stimulation system. For example, in some embodiments, an electrode assembly is included in the garment. As such, when the garment is donned by the patient, the electrode assembly is also donned by the patient. In some embodiments, the garment is configured to align the electrode assembly at the desired position with respect to the bodily tissue. The garment can be, for example, a sleeve, a strap, a belt, a vest, or the like. In other embodiments, an electrode assembly is coupled to a bodily tissue using a combination of an adhesive and a garment.

In some embodiments, as illustrated in FIGS. **59**-**61**, a stimulator system **1100** according to an embodiment is configured for use with an electrical lead implanted into the patient's bodily tissue T. The stimulator system **1100** and its components can be similar in many respects to stimulator system **1000** and its respective components, described in detail above. The stimulator system **1100** includes a stimulator assembly **1110** (FIG. **59**) and a disposable electrode assembly **1140** (FIG. **60**). The stimulator assembly **1110** includes a housing **1112**, a stimulus generator **1120** (shown in dashed lines in FIG. **59**), a power source **1130** (shown in dashed lines in FIG. **59**), an electrical pathway (not shown), and a first connector assembly (not shown). The stimulator assembly **1110** and its components can be similar in many respects to simulator assembly **1010** and its components, described above. The stimulator assembly **1110** is removably couplable to the electrode assembly **1140**. Specifically, the electrode assembly **1140** includes a second connector assembly **1144** removably couplable to the first connector assembly of the stimulator assembly **1110**. The second connector assembly **1144** includes a first connector **1145** and a second connector **1147**. Each of the connectors **1145**, **1147** is configured to be received by the first connector assembly. The electrode assembly **1140** includes a first electrode **1142** and a second electrode **1142**. The electrodes **1142**, **1143** can be any suitable electrode described herein (e.g., electrode **1042**).

As illustrated in FIG. **61**, each of the first electrode **1142** and the second electrode **1143** is configured to contact the bodily tissue T and to facilitate transmission of an electrical stimulation E through the bodily tissue, for example through subcutaneous bodily tissue located below and/or between the first electrode and the second electrode. The first electrode **1142** is configured to facilitate transmission of the electrical stimulation E from the stimulator assembly **1110** through the bodily tissue T. The first electrode **1142** can facilitate transmission of the electrical stimulation E to an electrical lead L at least partially implanted within the bodily tissue, as illustrated in FIG. **61**. For example, in some embodiments, the first electrode **1142** is a cathode configured to help transmit the electrical stimulation to a receiver (or pick-up) end of the electrical lead L. The second electrode **1143** is configured to receive at least a portion of the electrical stimulation E. As illustrated in FIG. **61**, for example, the second electrode **1143** can receive electrical stimulation E that has passed through the bodily tissue T and/or through the electrical lead L at least partially implanted within the bodily tissue. For example, in some embodiments, the second electrode **1143** is an anode configured to receive at least a portion of the electrical stimulation E from a stimulating end of the electrical lead L. In this manner, the stimulator system **1100** is configured to reduce loss of the electrical stimulation within the bodily tissue when the system is used with the implanted lead. Specifically, because the electrodes **1142**, **1143** are positionable over the pick-up end and stimulating end, respectively, of the electrical lead L, the electrode assembly **1140** is configured to increase a pick-up ratio of the electrical current C as compared to an electrode assembly with a smaller footprint preventing the electrodes from being positioned proximate to ends of the electrical lead.

The electrodes **1142**, **1143** are configured to adhere to bodily tissue (e.g., the skin) of the patient. Each electrode **1142**, **1143** of the electrode assembly **1140** includes a gel on the tissue-facing surface of the electrode. The gel can be any suitable known gel including, but not limited to, wet gels, karaya-gum-based hydrogels, and/or synthetic copolymer-based hydrogels. The first electrode **1142** and second electrode **1143** can be, for example, a cathodic gel electrode and an anodic gel electrode, respectively. Although the electrode assembly **1140** has been illustrated and described herein as including two electrodes **1142**, **1143**, in other embodiments, an electrode assembly can include any suitable number of electrodes. For example, an electrode assembly can include three, four, or more electrodes.

Although the electrode assembly **1140** has been illustrated and described herein as including a connector assembly **1144** and two electrodes **1142**, **1143**, in other embodiments, an electrode assembly can include additional components. For example, in some embodiments, an electrode assembly includes a support portion. The support portion can be configured to provide additional structural support or reinforcement, for example, to a portion of the electrode(s). In another example, the support portion can be configured to facilitate coupling of the electrode assembly to the stimulator assembly. In yet another example, an electrode assembly can include a tab configured to held by a user to facilitate removal of the electrode assembly from the bodily tissue.

Although the stimulus generator **1120** and the power source **1130** have been illustrated and described as being spaced apart within the stimulator assembly, in other embodiments, a stimulator assembly can include a stimulus generator and a power source disposed in another configuration. For example, in some embodiments, a stimulator assembly can include a stimulus generator that is disposed in a stacked configuration on top of the power source, or vice versa. In another example, in some embodiments, a stimulator assembly can include a stimulus generator and a power source that are disposed in close proximity to each other (e.g., side by side within the housing). Any suitable design configuration of the stimulus generator and power source may be used. In this manner, the stimulator assembly can have a more compact configuration.

In use, the stimulator system **1100** is disposed on the target bodily tissue and stimulation of the bodily tissue is initiated by the operator. The stimulator assembly **1110** can be removed from the electrode assembly **1140** for bathing, swimming, or other activity, however the electrode assembly can remain disposed on (or adhered to) the bodily tissue. Following the activity, the stimulator assembly **1110** is reattached to the electrode assembly **1140** and selective stimulation of the bodily tissue can be resumed. The stimulator assembly **1110** is generally removed from the electrode assembly **1140** and recharged daily using the external charger. After recharging, the stimulator assembly is reattached to the electrode assembly **1140**. The electrode assembly **1140** can be replaced on a weekly basis, or a needed. The stimulator assembly **1110** can be replaced annually, bi-annually, or as needed, for example, when the power source **1130** will no longer maintain a charge sufficient for powering the stimulus generator **1120** for a desired period of time.

FIG. **48** is a flow chart of a method **670** of assembling a portion of a stimulator assembly according to an embodiment. The method includes folding a tab portion of a flexible substrate such that the tab portion of the flexible substrate is in contact with a bottom side of a body portion of the flexible substrate and such that an electrical circuit formed on a top side of the flexible substrate extends about an edge of the fold, **675**. The flexible substrate can be any substrate of the types shown and described herein (e.g., PCB **202**, PCB **792**, substrate **380**, substrate **480**, substrate **580**). In some embodiments, the tab portion of the flexible substrate is bonded to the bottom side of the body portion of the flexible substrate. The electrical circuit can be formed on the top side of the flexible substrate in any manner shown and described herein. For example, the electrical circuit can be printed on the substrate. In another example, the electrical circuit can be partially embedded in the substrate such that a portion of the electrical circuit is exposed on a surface of the substrate.

In some embodiments, the method optionally includes coupling a portion of the flexible substrate to a rigid base, **680**. The base can be, for example, any of the bases shown and described herein (e.g., base **372**). The flexible substrate can be coupled to the rigid base in any suitable manner. In some embodiments, for example, at least a portion of the flexible substrate is woven through one or more openings defined by the rigid base (e.g., similar to the coupling of substrate **380** and base **372** shown and described above). The flexible substrate can, for example, be woven through a set of slots defined by the base.

In some embodiments, the method optionally includes disposing a first portion of the flexible substrate that includes the electrical circuit over a protrusion of the rigid base such that the first portion of the flexible substrate is non-parallel to a second portion of the flexible substrate, **685**. For example, in some embodiments, the flexible substrate is disposed over the protrusion of the base similar to the disposal of substrate **380** over the protrusion **374** of the base **372** as shown and described above.

In some embodiments, the method optionally includes folding a second tab portion of the flexible substrate such that the second tab portion of the flexible substrate is in contact with the bottom side of the body portion of the flexible substrate and such that the electrical circuit extends about an edge of the fold of the second tab portion, **690**. For example, in some embodiments, the second tab of the flexible substrate can be folded such that the substrate is in the second configuration as illustrated in FIGS. **45-47** and described above with respect to substrate **580**.

Although the method **670** of assembling a portion of a stimulator assembly has been illustrated and described in one order, the activities can occur in a different order. For example, in some embodiments, the substrate is coupled to the rigid base prior to folding the tab portion of the flexible substrate. Furthermore, each activity is not required for assembling the portion of the stimulator assembly. For example, in some embodiments, a portion of the electrical circuit can be disposed on the top and bottom side of the second tab portion, wherein the second tab portion need not be folded to extend the electrical circuit about an edge of the fold of the second tab portion. Additionally, certain of the events may be performed concurrently in a parallel process when possible.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. While the embodiments have been particularly shown and described, it will be understood that various changes in form and details may be made. For example, although the apparatus have been shown and described above as including a certain number of electrodes, in other embodiments, any suitable number of electrodes can be included. Further, elements of each embodiment described herein may be combined in any suitable manner with one or more elements of another embodiment described herein. For example, a hydrogel electrode may be selectively used with any of the foregoing apparatus, regardless if an embodiment was specifically described as including a hydrogel electrode. In another example, where an apparatus is shown and described herein as including a mechanical connector for connection to an external stimulator, in other embodiments, the apparatus can include a wireless connector for connection to the external stimulator.

Although various embodiments have been described as having particular features and/or combinations of components, other embodiments are possible having a combination of any features and/or components from any of the embodiments as discussed above. For example, a stimulation system according to an embodiment can include a base similar to the base **372** as described above and a folded substrate similar to the substrate **580** as described above.

Thus, the breadth and scope of the invention should not be limited by any of the above-described embodiments, but should be defined only in accordance with the following claims and their equivalents. The previous description of the embodiments is provided to enable any person skilled in the art to make or use the invention. While the invention has been particularly shown and described with reference to embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

An experiment was performed utilizing a first apparatus **990** and a second apparatus **991** according to an embodiment of the invention, as illustrated in FIG. **49**, to estimate the leakage current when each of the first apparatus and the second apparatus is immersed in solutions encountered during daily activities. Apparatus **990** includes a first metal connector **992** and a second metal connector **994**. Apparatus **991** was cut in the middle and the cut was filled with hot glue **997** to increase impedance between a first metal connector **993** and a second metal connector **995**, as illustrated in FIGS. **49** and **50**. Impedance of both direct current (DC) and alternating current (AC) was measured between the two metal connectors **992**, **994** of the first apparatus **990**. Impedance of both DC and AC was measured between the two metal connectors **993**, **995** of the second apparatus **991** prior to submersion in the liquid. AC impedance was measured between the two metal connectors **992**, **994** of the first apparatus **990** while the first apparatus was attached to skin of a patient. AC impedance was measured between the two metal connectors **993**, **995** of the second apparatus **991** while the second apparatus was attached to the skin of the patient.

Each of the first apparatus **990** and the second apparatus **991** was submerged in a liquid with a 3V Lithium coin battery attached to its respective metal connectors, as illustrated in FIG. **51** with reference to apparatus **991**. The discharge current and voltage were each measured for each apparatus **990**, **991** when the apparatus was submerged. Each of the discharge current, voltage and impedance were measured after removing the each apparatus **990**, **991** from its respective liquid submersion. Additionally, each of the discharge current, voltage and impedance were measured after slight wiping of the each apparatus **990**, **991**. Each apparatus **990**, **991** was then washed with tap water. These steps were performed for each of the following liquids: tap water, hot tub water, and saline solution. The discharge current showed an expected battery discharge, while AC impedance may represent leakage of the stimulation current on the patch rather than through bodily tissue. All AC impedance measurements were performed at 1 KHz. The results are shown in Table 1, below.

TABLE 1

Effects of Various Liquids on the Apparatus*

| | Apparatus 990 | | Apparatus 991 | |
|---|---|---|---|---|
| | Battery current | Impedance | Battery leakage | Impedance |
| Submersion in tap water | 1.5 mA | | 1.6 mA | |
| Removal from tap water | 0.6 mA | 2.0 Kohm<br>27 nF | 0.1 mA | ∞ Kohm<br>49 pF |
| After wiping | 0.3 mA | 300 Kohm<br>2.0 nF | >0.1 mA | ∞ Kohm<br>30 pF |
| Submersion in hot tub water | 2 mA | | 2.2 mA | |
| Removal from hot tub water | 0.8 mA | 2.0 Kohm<br>13 nF | 0.07 mA | 1.7 Kohm<br>1.2 nF |
| After wiping | 0.5 mA | 90 Kohm<br>1.0 nF<br>(130 Kohm after absorbing water with napkin) | >0.01 mA | 230 Kohm<br>128 pF |
| Submersion in saline solution | 9 mA | | 10 mA | |
| Removal from saline solution | 0.4 mA | 0.34 Kohm<br>212 nF | 0.04 mA | 3.5 Kohm<br>1.7 nF |
| After wiping | 0.3 mA | 0.5 Kohm<br>134 nF | >0.01 mA | 230 Kohm<br>94 nF |

*Before submersion, DC impedance approached infinity; AC impedance R approached infinity, C = pF; Impedance on the skin (AC) R = 8.3 Kohm, C = 36 nF. Battery voltage (when connected to the immersed patch) was 2.8-2.9 v.

The results indicate that daily use of a bath or hot tub for 20 minutes drains 0.5-0.7 mAh per use (or 3.5-4.9 mAh per week). Assuming that the apparatus **991** incorporates a power source similar to a cr2032 coin lithium battery (225 mAh capacity), this drain is insignificant. A daily swim in ocean water for 20 minutes will drain ~3.3 mAh per day (or ~21 mAh per week), which is insignificant when compared to the suggested power source capacity. Further, the current drain during the drying period of 1 hour (for apparatus **990**) is less than 1 mA per use (7 mAh per week) and does not add significant discharge compared with the power source capacity. After removal from the liquid, apparatus **991**, which has a hydrophobic plastic barrier (similar to barrier **218** described above) ensures significantly lower power source discharge current compared to apparatus **990**, which lacks a barrier. A significant amount of electrical current escapes via apparatus **990** and would not be expected to reach the body when apparatus **990** is exposed to liquid. However, apparatus **991** would be expected to divert most of the electrical current to the body, if wiped.

What is claimed is:

**1**. An apparatus, comprising:

a rigid base having a protrusion, the base configured to be coupled to an electronic device; and

a flexible substrate having a first surface and a second surface and including an electrical circuit configured to electronically couple the electronic device to an antenna, the antenna coupled directly to the flexible substrate, the flexible substrate coupled to the base such that a first portion of the second surface is in contact with the protrusion, a second portion of the second surface is non-parallel to the first portion.

**2**. The apparatus of claim **1**, wherein at least a first portion of the flexible substrate is disposed within a first slot defined by the base, at least a second portion of the flexible substrate is disposed within a second slot defined by the base, the first slot different than the second slot.

**3**. The apparatus of claim **1**, wherein the base defines a plurality of slots, each slot of the plurality of slots configured to receive a portion of the flexible substrate.

**4**. The apparatus of claim **1**, wherein:

a first portion of the first surface of the flexible substrate includes at least a portion of the electrical circuit, the portion of the electrical circuit configured to be in electrical communication with an electrical contact disposed on a first portion of the electronic device; and

the base includes a second protrusion configured to engage a second portion of the electronic device when the electronic device is coupled to the base, the second portion of the electronic device different than the first portion of the electronic device.

**5**. The apparatus of claim **1**, further comprising:

a hydrogel electrode coupled to the second surface of the substrate, the substrate further including a conductive region electrically coupled to the electrical circuit and a plurality of non-conductive regions configured to facilitate retention of the hydrogel electrode with respect to the second surface of the substrate.

**6**. An apparatus, comprising:

a flexible housing configured to be disposed about at least a portion of a stimulator assembly, the stimulator assembly including at least a battery, an electrode, and a stimulus generator, the housing including a receiving portion configured to receive at least a portion of the stimulus generator, the receiving portion defining a first opening configured to receive a protrusion of the stimulus generator when the stimulus generator is received in the receiving portion such that the stimulus generator is electrically coupled to the battery, the receiving portion defining a second opening different than the first opening, the second opening configured to receive a protrusion of a base of the stimulator assembly such that the protrusion can limit movement of the stimulus generator with respect to the housing when the stimulus generator is received in the receiving portion of the housing.

**7**. The apparatus of claim **6**, wherein a portion of the housing is configured to form a substantially fluid-tight seal proximate to the receiving portion when at least the portion of the stimulus generator is received in the receiving portion.

**8**. The apparatus of claim **6**, wherein the housing defines a recess configured to receive a fastening member of the stimulator assembly, the fastening member configured to limit movement of the housing relative to the stimulator assembly when the housing is disposed about the portion of the stimulator assembly and the fastening member is received in the recess.

**9**. The apparatus of claim **6**, wherein the housing is configured to substantially maintain the stimulus generator in electrical communication with an electrical pathway coupled to a substrate of the stimulator assembly when the stimulus generator is received in the receiving portion, the electrical pathway electrically couples the stimulus generator to at least one of the electrode or the battery.

**10**. A method, comprising the steps of:

folding a tab portion of a flexible substrate such that the tab portion of the flexible substrate is in contact with a bottom side of a body portion of the flexible substrate and such that an electrical circuit formed on a top side of the flexible substrate extends about an edge of the fold, the flexible substrate configured to be coupled to a body.

**11**. The method of claim **10**, further comprising:

coupling at least a portion of the flexible substrate to a rigid base.

**12**. The method of claim **10**, further comprising:

disposing a first portion of the flexible substrate including the electrical circuit over a protrusion of a rigid base such that the first portion of the flexible substrate is non-parallel to a second portion of the flexible substrate.

**13**. The method of claim **10**, further comprising:

weaving at least a portion of the flexible substrate through a slot defined by a rigid base.

**14**. The method of claim **10**, wherein the tab portion is a first tab portion, further comprising:

folding a second tab portion of the flexible substrate such that the second tab portion of the flexible substrate is in contact with the bottom side of the body portion of the flexible substrate and such that the electrical circuit extends about an edge of the fold of the second tab portion.

**15**. An apparatus, comprising:

a hydrogel electrode; and

a substrate including a lower surface, a conductive region, and a plurality of discrete non-conductive regions, the conductive region electrically coupled to an electrical circuit of the substrate and to the hydrogel electrode, the plurality of discrete non-conductive regions configured to facilitate coupling of the hydrogel electrode with the lower surface of the substrate, at least one non-conductive region of the plurality of discrete non-conductive regions extending beyond a surface of the conductive region.

**16**. An apparatus, comprising:

a hydrogel electrode; and

a substrate including a lower surface, a conductive region, and a plurality of discrete non-conductive regions, the conductive region electrically coupled to an electrical circuit of the substrate and to the hydrogel electrode, the plurality of discrete non-conductive regions configured to facilitate coupling of the hydrogel electrode with the lower surface of the substrate, at least one non-conductive region of the plurality of discrete non-conductive regions is at least one of (1) a solder mask, (2) a cavity formed in a surface of the conductive region, or (3) formed by a coating applied to a surface of the conductive region.

**17**. The apparatus of claim **16**, wherein at least one non-conductive region of the plurality of discrete non-conductive regions is formed by a coating applied to the surface of the conductive region.

**18**. The apparatus of claim **16**, wherein at least one non-conductive region of the plurality of discrete non-conductive regions is a cavity formed in a surface of the conductive region.

**19**. The apparatus of claim **16**, wherein at least one non-conductive region of the plurality of discreet non-conductive regions is a solder mask.

**20**. The apparatus of claim **1**, wherein the electrical circuit is configured to electronically couple the electronic device to at least one of an electrode or a battery.

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